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Environmental Research Laboratory

October 1975

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SECOND ANNOTATED BIBLIOGRAPHY ON BIOLOGICAL EFFECTS OF METALS IN AQUATIC ENVIRONMENTS

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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[No. 568-1292]

by

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ABSTRACT

A total of 725 references are listed on the toxicological, physiological, and metabolic influence of stable and radiolabelled chemical species of metal cations to marine, estuarine, and freshwater fauna and flora. References were annotated and subsequently indexed by metal, by taxa, and by author, in cumulative indices which encompass this volume and the initial volume in this series (Eisler, R. 1973. Annotated bibliography on biological effects of metals in aquatic environments (No. 1-567). U.S. Envir. Prot. Agen. Rept. R3-73-007: 287 pp.).

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SECTION I

INTRODUCTION

A growing body of literature has become available in recent years on biological effects of metals on marine, estuarine, and freshwater biota. Much of this information is of recent vintage as evidenced by the fact that the majority of references listed herein have been published within the past five years. We attribute this increase in published data to technological advances and increasing utilization of atomic absorption spectrophotometry, neutron activation, and other techniques used in quantitative determination of metals in biological matrices.

As was true in the initial volume, published as EPA Report R3-73-007, the present account lists journal articles and reports that emphasize toxicological, physiological and metabolic effects of stable and radioactive species of metal cations to aquatic life. Specifically: factors affecting survival, growth, reproduction, behavior, and bioaccumulation; influence of changes in exogenous salt content on response parameters including internal changes in salt balance of body fluids and tissues; baseline data on elemental composition; and finally, interaction effects of metals and their salts in combination with other substances.

As more information becomes available, and future volumes in this series are produced, it is hoped that levels for each metal can be established administratively which do not jeopardize the stability of aquatic ecosystems or present a potential health hazard to man through aquatic food chains.

SECTION II

REFERENCES

References are arranged alphabetically by author and then numbered. Each reference is indexed by metal(s), by author(s) and by taxonomic group(s) in the INDEX (Section III).

568. Abdelmalik, W.E.Y., R.M.K. El-Shinawy, M.M. Ishak, and K.A. Mahmoud. 1973. Uptake of radionuclides by some aquatic macrophytes of Ismailia Canal, Egypt. Hydrobiologia 42(1): 3-12.

The uptake and accumulation of Cs-134, Co-60, Sr-90, and P-32 were studied with four aquatic macrophytes: *Elodea densa*, *Ceratophyllum demersum*, *Potamogeton pectinatus*, and *Chara* sp. Tests were conducted with plants in large aquaria containing canal water labelled with the radionuclides. Authors concluded that uptake of the radionuclides increased at increasing initial concentrations of the radionuclides in the water; that maximum uptake was reached by most plants after different periods of contamination, ranging from 1 to 4 days; that *Ceratophyllum* was the most favorable biological indicator for strontium radioisotopes in concentrations ranging from 0.5 to 10 microcuries/l and for contamination periods up to 16 days; that *Elodea* was a good biological indicator for either strontium or phosphorus radioisotopes for limited contamination periods of 2 to 16 days for Sr and to 2 days for P isotopes; and finally, that *Potamogeton* was also a good biological indicator for limited contamination periods for strontium, phosphorus and cesium radioisotopes: 0 to 2 days for Sr, 2 to 16 days for P, and 0 to 2 days for Cs isotopes.

569. Ackefors, H., G. Löfroth, and C.G. Rosén. 1970. A survey of the mercury pollution problem in Sweden with special reference to fish. Oceanogr. Mar. Biol. Ann. Rev. 8:203-224.

The intentional and unintentional mercury pollution in Sweden has given rise to a serious problem which embraces hazards for all types of biological ecosystems. The recent finding that other types of mercury compounds may end up as methyl-Hg by the action of microorganisms occurring in natural waters forces us to look upon this problem as even more serious. The fact that mercury contained in fish is 70-100% methyl-Hg is alarming. In about 1% of the waters investigated in Sweden the mean value of mercury concentration in fish exceeds 1000 ng/g; such fish are definitely unfit for human consumption, and it is now forbidden to market such fish in Sweden. In addition mercury residues have been reported in many types of agriculturally produced food and in wildlife. The mercury concentrations seem to be higher in kidneys and liver than in skeletal muscles of terrestrial animals. There are, however, examples of very high concentrations in the flesh of pheasants. In contaminated water, fish have generally higher concentrations in muscle than in liver and kidney.

The mercury problem may be more serious in Sweden than in some other countries due to climatic and biological factors and to the widespread use of mercury in industry and agriculture, but there is every reason to believe that the problem is of similar magnitude in other countries, especially with regard to aquatic organisms; the main difference is that the problem has not been observed elsewhere, and this is because until now very few investigations have been made outside of Japan and Sweden. From the current point of view it is extremely important that all countries take an interest in this problem and as far as possible begin to restrict the mercury contamination of soil, water, and air in order to prevent the great hazards for mankind which increased mercury concentrations in nature imply. The reported cytological effects on man and other organisms are a disturbing aspect of this pollution problem.

570. Adam, F.S., H. Cole Jr., and L.B. Massie. 1973. Element constitution of selected aquatic vascular plants from Pennsylvania: submersed and floating leaved species and rooted emergent species. Environ. Pollut. 5:117-147.

Thirty species of submersed and floating leaved aquatic vascular plants (AVPs) and fifteen species of rooted emergent AVPs were collected from forty-four and forty-two locations, respectively, in the Delaware, Susquehanna and Allegheny river watersheds in Pennsylvania (USA) and analyzed by emission spectrometry for element constitution of eleven potentially-polluting ions including: phosphorus, potassium, calcium, magnesium, manganese, iron, copper, boron, aluminum, zinc, and sodium. These species were characterized according to intraspecific variation in element constitution, significant statistical variation for each ion within each species between locations and species potential for monitoring nutrient pollution.

Macro and micro element constituent levels for twenty-one additional species of submersed and floating leaved AVPs and for eight additional species of rooted emergent AVPs, collected at one or two locations each were also determined. *Elodea canadensis*, *Potamogeton crispus*, *Myriophyllum exalbescens*, *Justicia americana*, and the *Sparganiums* have been selected for additional studies designed to investigate pathways of nutrient assimilation and the effect of nutrient pollution upon productivity, morphology and reproduction.

571. Albright, L.J., J.W. Wentworth, and E.M. Wilson. 1972. Technique for measuring metallic salt effects upon the indigenous heterotrophic microflora of a natural water. Water Research 6(12): 1589-1596.

The effects of several concentrations of the metallic salts Ag_2SO_4, $NaAsO_3$, $BaCl_2 \cdot 2H_2O$, $CdCl_2 \cdot 2.5\ H_2O$, $CrCl_2 \cdot 6H_2O$, $CuCl_2$, $HgCl_2$, $NaCl$, $NiCl_2 \cdot 6H_2O$, $PbCl_2$ and $ZnCl_2$ upon the indigenous heterotrophic microflora of a natural water were studied. Effects of these salts upon the heterotrophic activity of the microbes were assayed using the heterotrophic technique whereas lethal effects upon the heterotrophic bacteria were determined using nutrient agar plate counts. The heterotrophic activity method is based upon the uptake and mineralization of a radioactively labeled metabolite (in these experiments ^{14}C-glucose) by the indigenous aquatic microbes and data analysis is by Michaelis-Menten enzyme kinetics equations. Concentrations of metallic salts which resulted in bacterial death also caused erratic uptake and mineralization rates of ^{14}C-glucose whereas sub-lethal concentrations, as determined by nutrient agar plate counts, caused a non-competitive inhibition of maximum heterotrophic activity and markedly increased the turnover time of the glucose substrate.

572. Albright, L.J., and E.M. Wilson. 1974. Sub-lethal effects of several metallic salt-organic compounds combinations upon the heterotrophic microflora of a natural water. Water Research 8:101-105.

Effects of several sub-lethal combinations of the metallic salts Ag_2SO_4, $CuCl_2$, $HgCl_2$ and $ZnCl_2$ with the organic compounds L-cysteine and albumin upon heterotrophic activity of the microflora of a natural water are studied. This heterotrophic activity technique is based upon uptake and mineralization of a labeled metabolite by indigenous microflora from a reflecting pool. Data analysis by Michaelis-Menten enzyme kinetics equations allows the estimation of maximum rate of heterotrophic activity as well as a determination of turnover time of the nutrient in question. Addition of a sub-lethal combination of Cu and Zn to a sample of pool water decreases heterotrophic activity to approximately the same extent as the additive decrease caused by these two cations added separately to samples of this water. Cu and Zn treated water samples do not recover the pre-metallic salt treatment activity following a 3-day incubation. Both L-cysteine and albumin have no protective effect upon heterotrophic activity inhibition caused by Hg and Ag respectively at the concentrations used.

573. Alderdice, D.F., and C.R. Forrester. 1971. Effects of salinity, temperature, and dissolved oxygen on early development of the Pacific cod (Gadus macrocephalus). Jour. Fish. Res. Bd. Canada 28(6):883-902.

Effects of various combinations of levels of salinity, temperature and dissolved oxygen on incubation of Pacific cod eggs were investigated in the laboratory. These eggs are judged to be euryhaline, euryoxic, and stenothermal. As long as temperatures are within the range of about 3-5°C, the developing egg is tolerant of a wide range of salinities (optimum 15°/oo), and of dissolved oxygen levels to a minimum of about 2 or 3 mg/l. Below 3°C developmental success decreases precipitously; above 5°C it attenuates more slowly.

574. Alderdice, D.F., and F.P.J. Velsen. 1971. Some effects of salinity and temperature on early development of Pacific herring (*Clupea pallasi*). Jour. Fish. Res. Bd. Canada 28: 1545-1562.

Pacific herring eggs were incubated in the laboratory at 13 different salinity-temperature combinations (ranges: 5-45^{o}/ooS, 4-14°C). Data were obtained on rate of development, larval length at hatching, percent total hatch, and percent viable hatch. Maximum percent viable hatch, larval size at hatching, and maximum survival to yolk sac absorption occurred at 16.41^{o}/ooS, 6.85°C. Optimum conditions were calculated by response surface analysis--maximum total hatch: 12.01^{o}/ooS, 6.46°C; maximum viable hatch: 16.98^{o}/ooS, 8.33°C; maximum length of newly hatched larvae: 20.00^{o}/ooS, 5.54°C. Maximum percent viable hatch of largest larvae in the shortest incubation period is estimated to occur at or near 16.98^{o}/ooS, 8.7°C. Pacific herring eggs are considered euryhaline and stenothermal. A comparison of laboratory and field observations suggests that occurrence and abundance of herring is related to the availability and extent of spawning salinities between 8 and 28^{o}/oo. Moreover, catch statistics suggest that population abundance in North American waters is associated with spawning temperature of 5-9°C, abundance is limited by temperatures of 9-10°C, and the maximum temperature for spawning is about 10°C.

575. Al-Hamed, M.I. 1971. Salinity tolerance of common carp: (*Cyprinus carpio*, L.). Bull. Iraq Nat. Hist. Mus. (Univ. Baghdad), 5(1):1-7. *In* Selected Water Resources Abstracts, 5(21):74.

C. carpio, ranging in length from 8.5 to 12.7 cm were exposed directly and gradually to different salinity levels. In direct exposure experiments, fish lived at salinities as high as 12^{o}/oo for 10 weeks (the duration of the experiment). Higher salinities proved unfavorable. In gradual acclimatization experiments during a period of 4 days fish lived at salinities as high as 17^{o}/oo, but higher levels were lethal. Fertilized ova of carp hatched at salinities from 2^{o}/oo to 10^{o}/oo, but the favorable level was up to 6.6^{o}/oo.

576. Allen, K.O., and J.W. Avault, Jr. 1970. Effects of salinity on growth and survival of channel catfish, *Ictalurus punctatus*. Proc. 23rd Ann. Conf. Southeast Assoc. Game and Fish Commrs., 1969: 319-331.

Three-day old or older eggs tolerated up to 16°/oo total salinity. However, at time of hatching there was a sharp drop in tolerance to about 8°/oo. This level of tolerance was maintained during the period of yolk absorption. Following yolk absorption, there was an increase in tolerance to about 9 or 10°/oo. By five months of age tolerance had increased to 11°/oo and to 12°/oo by six months. The level of tolerance was about the same at 11-14 months. Nine days acclimation to 5°/oo increased growth and food conversion slightly but did not increase survival. Forty days of acclimation to 5°/oo increased tolerance about 0.5°/oo. Fish failed to maintain themselves at salinities greater than 12°/oo, even with extended acclimation to 10°/oo salinity. In long-term studies, starting at an age of 42 days and continuing through an age of 148 days, fingerlings in freshwater had the best indices for food consumption, growth, food conversion, and survival. Fingerlings in 5°/oo salinity did almost as well. Fingerlings in 10°/oo salinity were a poor third. In long-term studies with 11 through 14 month-old yearlings, when fish were acclimated to 5°/oo, indices were similar at all test salinities of 0 through 11°/oo. Fish acclimated to 10°/oo gave similar results at 0 through 12°/oo.

577. Alley, W.P. H.R. Brown, and L.Y. Kawasaki. 1974. Lead concentrations in the wooly sculpin, *Clinocottus analis*, collected from tidepools of California. *California Fish and Game* 60(1): 50-51.

Lead concentrations in muscle from *Clinocottus analis* was examined for 12 fishes collected in the tidepools of the Pt. Fermin area of Los Angeles, 9 fishes taken from tidepools 11 miles north of San Simeon, and 9 fishes removed from tidepools near the isthmus of Santa Catalina Island. Average lead values at Pt. Fermin was 4.9 mg/kg while the average lead level of sculpins collected at the isthmus of Santa Catalina Island was 2.7 mg/kg. Mean values for sculpins removed north of San Simeon was only 0.6 mg/kg. Lead values of tidepool fishes in San Simeon were of a magnitude similar to levels reported for salmon (1.3 mg/kg), tuna (0.9 mg/kg), sardines (1.1 mg/kg), anchovies (0.9 mg/kg), and swordfish (0.2 mg/kg) by other investigators. The lead concentration of the Pt. Fermin wooly sculpins were almost five times greater than previously mentioned values while the Santa Catalina sculpins contained more than twice as much lead.

Geographical variations in lead levels in these tidepool fishes undoubtedly reflects contamination of the intertidal zone by atmospheric lead pollution; documentation exists to show that the inner city of the Los Angeles Metropolitan Area contained almost 35 times more atmospheric lead than remote mountainous areas of California and almost 9 times more atmospheric lead than "composite rural areas."

The San Simeon region easily qualifies as a rural area in that it is removed from any major metropolitan area and that it has no major highways passing through it; it is more than a coincidence that lead levels in tidepool fishes from this area are about 8 times less than the Los Angeles area. Santa Catalina Island is separated from the mainland by the Santa Catalina Channel with the isthmus being about 19 miles southwest of Pt. Fermin. Authors conclude that S.C. island lies close enough to L.A. to receive some of its atmospheric pollution. This conclusion is supported by the fact that lead concentrations of tidepool fishes of the isthmus area are about half as great as at Los Angeles but more than four times greater than the San Simeon area.

This study represents a preliminary examination of the lead concentration of one species of intertidal fish and suggests that levels of lead in the intertidal environment may vary from metropolitan areas to rural areas; however, it does not indicate how the lead enters the food chain or the levels existing in the intertidal invertebrates and other intertidal fishes. Perhaps this common intertidal fish can be used as an indicator organism to reflect the accumulation of lead in the intertidal environment which is derived from air pollution.

578. Amend, D.F. 1970. Retention of mercury by salmon. Progr. Fish-Cult. 32(4):192-194.

The juvenile sockeye salmon treated repeatedly with mercurials accumulated and retained high levels of mercury in their tissues for several months, but after 4 years at sea they contained normal levels of mercury in all tissues examined. Adult chinook and coho salmon also treated with mercurials as juveniles did not show abnormal levels of mercury. However, adult salmon exposed to mercury upon returning from the sea, or mercurial-treated juvenile fish, may contain abnormal levels of mercury.

579. Amiard-Triquet, C., and J.C. Amiard. 1974. Contamination de chaines trophiques marines par le cobalt 60. Rev. Inter. Océanogr. Médicale 33:49-59.

Passage of Co-60 from the annelid Arenicola marina to the upper trophic level constituted by the crab Carcinus maenas or flounder Pleuronectes platessa, was studied.

Co-60 absorption and excretion by fecal, urinary and branchial routes were measured following administration of contaminated food during periods from one to five months. Elimination of Co-60 by crab and flounder was monitored during six and three months respectively. Assimilation of radioactive and stable cobalt found as a carrier in the contaminated food varied according to the species; assimilation rates were high in *C. maenas* and very low in *P. platessa*. Cobalt isotopes were mainly retained in the hepatopancreas of crabs and in liver and kidney of flounder.

The high concentrations of Co-60 in these organs could result in very partial internal exposures but nevertheless, comparatively high; these are long-term exposures because cobalt has a low exchange rate.

580. Anas, R.E. 1971. Mercury in fur seals. *In* Buhler, D.R. (ed.), "Mercury in the Western Environment" Workshop, Portland, Oregon, Feb. 25-26, 1971: 91-96 (sponsored by Environ. Hlth. Sci. Cent., Oreg. State Univ., Corvallis, Oregon).

Fur seals (*Callorhinus ursinus*) off the Pribilof Islands, Alaska, were tested by flameless atomic absorption for mercury contamination. Liver, muscle and brain tissues were sampled from pup, young male and adult female seals. All of the samples contained mercury, though levels were higher in liver than muscle or brain. Mercury content in livers of pups was 0.20 mg/kg, 10.8 mg/kg for young males and 67.2 mg/kg for the adult females. While increased mercury levels in liver tissue were significantly correlated with age, muscle tissue showed no such correlation. Brain tissues were analyzed by neutron activation; mercury values were higher using this method than those determined by atomic absorption. The sources of mercury contamination off the Pribilof Islands have not yet been identified.

581. Anas, R.E. 1974. Heavy metals in northern fur seals, *Callorhinus ursinus*, and harbor seals, *Phoca vitulina richardi*. *U.S. Dept. Commerce Fish. Bull.* 72(1):133-137.

Samples of liver, muscle, and kidney from fur seal and liver from harbor seal were analyzed for total mercury. Liver and kidney of fur seals were analyzed for lead, cadmium, and arsenic. Fur seals were from the Pribilof Islands, Alaska, and from off the Washington coast. Harbor seals were from the waters of southern California, Oregon, Washington, and the Bering Sea. All of the samples, including a fetus taken 3 months before birth, contained mercury, lead, and cadmium. Arsenic was not detected. Mercury was highest in liver, followed by kidney, then muscle. The maximum concentration of mercury in liver was about 700 mg/kg in a southern California harbor seal and 170 mg/kg in a fur seal taken off the Washington coast. Concentrations of cadmium and lead were highest in the kidney (maximums of 1.8 mg/kg lead and 15.6 mg/kg cadmium) of fur seals. Concentrations of mercury did not correlate with age in muscle or kidney ($P > 0.05$) but did correlate significantly with age in liver ($P < 0.01$). Concentrations of cadmium and lead in liver and kidney did not correlate with age ($P > 0.05$). In samples of liver collected from harbor seals, the highest concentrations of mercury were from southern California seals.

582. Ancellin, J.C.M., M. Avargues, and P. Bovard. 1972. Study of a marine site with respect to discharges of radioactive effluents. In Ruivo, M. (ed.), Marine Pollution and Sea Life, Fishing Trading News (Books), Ltd., London: 180-186.

The discharge of radioactive effluents in the marine environment causes a potential risk of secondary irradiation of the populations due to the contamination of marine products and of their utilization for alimentary or other purposes. Definition of the limits of the discharges has to be taken from the studies and research concerning the transfers of radionuclides from their starting point until reaching man, through the components of the marine environment: water, sediments, living organisms. Research should also cover the eventual action of the radioactive substances on the biological equilibrium of the environment. Such studies have been undertaken by the Atomic Energy Commissariat, or under its direction, on the occasion of the opening at La Hague of a factory for treatment of irradiated combustibles. The authors describe the fields explored and the principal results obtained. They stress the importance of the physical and chemical state of the radionuclides in their evolution and their transfer to the marine environment. Specific examples are presented with isotopes of Ce, Cs, Ru, and Zr to algae, molluscs, crustaceans and fishes.

583. Ancellin, J., M. Avargues, P. Bovard, P. Guegueniat, and A. Vilquin. 1973. Aspects biologiques et physico-chimiques de la contamination radioactive d'especes et de sediments marins. In Radioactive Contamination of the Marine Environment, Int. Atom. Ener. Agen., Vienna, Austria: 225-243.

Various aspects of the physico-chemical and biological fate of radioactive pollutants in the marine environment are reviewed in the light of the results of recent radioecological research. Specific examples are presented with isotopes of Zn, Cs, Ce, Ru, Co, Cu, Pb, Mn, and Fe to fish, mollusca, algae, annelids and crustaceans. In studying contamination of any kind, it is necessary to take into account the relative importance of physico-chemical and biological processes that take place simultaneously. In a certain number of cases the mechanisms whereby elements present in small quantities in seawater are adsorbed on to living organisms are similar to those that apply to inert bodies. The contribution of the species to fixation of the element is passive, and the physico-chemical properties of the contaminants and of the contaminated carrier can dominate its own biological properties, particularly the physiological barrier of regulation. Various types of equilibration of the pollution of the organs, notably in fish, with the pollution of the environment are examined, together with the differences in the capability of various competing sites for adsorption of a specific pollutant. For example the capability of sediments on the one hand and the living species in contact with the sediments on the other.

584. Ancellin, J., and P. Bovard. 1971. Observations concernant les contaminations expérimentales et les contaminations "in situ" d'espèces marines par le ruthenium 106. Rev. Int. Oceanogr. Médicale 21:85-92.

Studies are briefly reviewed about uptake of Ru 106 by marine organisms from a bay receiving nuclear wastes. Concentration factors (ratio of the activity of the organism to that of an equal weight of water) were: algae (100-1,000), sponges (1,000-10,000), ascidians (1,000). The sample volume needed for water analysis was 40-80 liters. Suitable bioindicators of Ru contamination were: coralline algae, other algae, sponges, or the more rare ascidians. In laboratory studies in which insoluble suspensions of Ru compounds present in nuclear wastes were circulated in aquaria, concentration factors in agreement with the above were found; however, when only dissolved compounds were present in the water, the values were about an order of magnitude lower.

585. Ancellin, J., and A. Vilquin. 1966. Contaminations experimentales d'especes marines par le cerium-144 le ruthenium-106 and le zirconium-95. In Disposal of Radioactive Wastes into Seas, Ocean and Surface Water, Int. Atom. Ener. Agen., Vienna: 583-604.

Studies were conducted in aquaria of 40-to 70-l capacity, containing sea water and operating as a closed circuit, provided with sediment composed of sand or gravel, and equipped with a filtration-aeration system. Each aquarium is contaminated with one of the three following radioisotopes: cerium-144, ruthenium-106 and zirconium-95. The specific activity of the water in the aquaria is of the order of 1 to 2 µCi/l. A certain number of species were studied, either in isolation or preferentially with respect to others, and grouped in the same aquarium so as to reconstitute the biological environment observed along the northwest coast of the Cotentin Peninsula (Department of Manche.)

Fairly high build-up factors are observed for cerium-144, particularly with respect to the alga Corallina officinalis (of the order of 10,000 to 20,000). For ruthenium-106 the build-up factors are lower (e.g. about 100 to 200 for the algae investigated). These results may be compared with data already published on the same or similar species. They confirm that the concentration capability often varies inversely to the degree of evolution of the organisms, at least as far as two of the fission products in question are concerned: ^{106}Ru and ^{144}Ce.

As regards the concentration of cerium-144 in algae in particular, our values are higher than those mentioned in the literature. Differences have also been noted in the case of ruthenium-106.

586. Ancellin, J., and A. Vilquin. 1968. Nouvelles études de contaminations expérimentales d'espèces marines par le césium 137, le ruthénium 106 et le cérium 144. Radioprotection 3(3): 185-213.

Concentration factors for Cs 137, Ce 144 and Ru 106 were determined for various species of marine algae, coelenterates, molluscs, crustaceans, and fishes under controlled conditions. For algae CF were $\leq$ 40 for Cs, 100-200 for Ru and 2000-10,000 for Ce; for invertebrates, these values were $\leq$ 40 for Cs, 20-50 for Ru, and 500-2000 for Ce; with fishes these were $\leq$ 40 for Cs, 1 for Ru, and < 100 (1-5) for Ce.

587. Anderson, G.E., J.B. Gentry, and M.H. Smith. 1973. Relationships between levels of radiocesium in dominant plants and arthropods in a contaminated streambed community. Oikos 24(2):165-170.

For several years Steel Creek (South Carolina) received reactor cooling water and disassembly basin effluents from two nuclear production reactors located near the stream's headwaters. When the stream no longer received reactor effluent in 1968, water flow was reduced and portions of the old streambed became exposed. Contaminated vegetation then became available to animals as food. This account reports on radiocesium levels and concentration ratios of a plant-herbivore-predator food web. Mean cesium concentrations were significantly higher on the islands than on floodplain areas. There were no consistent trends for increasing or decreasing concentration across trophic levels. However, the degree of linear correlation between radiocesium concentrations in different types of plants and arthropods was significant and makes possible a model to predict radiocesium levels in other components of the system. Predictability was highest between the various arthropod groups and lowest among the different plant types. Between the two possible producer-herbivore-predator associations (broomsedge-grasshopper-spider, and broomsedge-leafhopper-spider) radiocesium concentrations ratios differed significantly.

588. Anderson, J.B., E.C. Tsivoglou, and S.D. Shearer. 1963. Effects of uranium mill wastes on biological fauna of the Animas River (Colorado-New Mexico). In Schultz, V., and A.W. Klement, Jr. (eds.), Radioecology. Reinhold Publ. Corp., New York: 373-383.

Bottom fauna in the Animas River from the mill to the New Mexico state line were much less abundant than above the mill and in unpolluted tributary streams. Few or none of the insects important as food for fishes were found in approximately 45 to 60 km of polluted river below the mill. Fly larvae were the most resistant to pollution and were found at nearly all stations.

The reduction of food supply and the direct toxic effects of the mill wastes reduced numbers of fish below the mill. This was verified with fish collections obtained by rotenone application. Some limited improvement was noted in late 1959 a few months after the institution of pollution abatement measures, but insufficient time had elapsed for substantial stream recovery.

There was a prolific growth of algae extending 36 km below the mill. Algae were less abundant 42 km below the mill, and appeared in normal quantity at 54 km. As the number of insects increased, the amount of algae decreased.

Toxicity tests using rainbow trout with various mill wastes were useful in determining the most harmful wastes. Median tolerance limit values ranged from 0.09 percent to 0.22 percent for organic raffinate wastes. Other wastes were less toxic. Based upon the volumes of wastes discharged to the river and their toxicity, it was estimated that about 70 m^3 per second were needed in 1958 to dilute wastes in the river to protect fish life.

By the fall of 1959 a program of waste treatment and storage of the most toxic waste in ponds had been effected. It was estimated from the toxicity studies that river dilution requirements had been reduced to 16 m^3/sec.

Data on radium-226 content of attached filamentous algae, aquatic insects, and fish from the Animas River and other streams provide much information on the fate of this material in aquatic environments. The natural, or background, radium-226 concentrations of these various forms have been shown, together with associated water and silt concentrations, and for the lower forms the radium-226 concentrations have been related to the gross alpha radioactivity.

The data have demonstrated similar radium-226 concentrations at both polluted and clean locations for the algae and aquatic insects, whence it has been concluded that the former might better serve as an indicator of the radium-226 pollution because of the relative ease of collection.

A relation between the radium-226 content of the algae and the associated dissolved radium-226 in water has been shown, and, while not precise, appears to be adequate for estimating purposes. It appears that algae samples are useful as indicators of radium-226 pollution.

Radium-226 concentration factors for algae, insects, and skeletons and flesh of large suckers (teleosts) have been derived and appear to be consistent among themselves and among the types of biota. Concentration factors for attached filamentous algae are in the range of 500 to 1,000; factors for aquatic insects are the same. Radium-226 concentration factors for sucker skeletons are about 100; for sucker flesh a factor of only three was observed, demonstrating the bone-seeking qualities of radium-226. Although only a small number of suckers were involved in these latter determinations, the results were consistent.

589. Andrushaitis, G., and Z. Kalnina. 1972. The cycling of radioactive sediments (strontium-90) in the lakes of Latvian SSR. Verhan. Internat. Verein. Limnologie 18(Part 2):995-1000.

Concentrations of strontium-90 in water and its uptake by plankton, plants, fish, substrates, and the calcium content of the water were measured in Latvian reservoirs of different trophic states to determine the accumulation and migration of radioactive wastes. Analyses of Sr-90 show that fish--Esox lucius, Perca fluviatilis, Abramis brama--accumulate more Sr-90 in a dystrophic lake than the same species in mesotrophic and eutrophic lakes. In considering different lake types, there was a marked difference between the types, Sr-90 concentration factor in a dystrophic and that of either eutrophic or mesotrophic lakes. Concentration factor for plankton, water plants, fish and substrates in a dystrophic lake is higher than in mesotrophic and eutrophic lakes, corresponding to their different ionic relationships. Sr-90 concentration in water and its accumulation by hydrobionts and lake substrates changes seasonally. In water it is highest during autumn and winter, lowest during summer. Sr-90 increases during plant vegetation period due to mineral increase. For fish it is higher in spring than autumn. Its increasing or decreasing concentration factor for plankton is connected with change in species and water pH, but for substrates it depends on substrate structure and its displacement.

590. Anon. 1970. Hazards of mercury. Special Report of Study Group on Mercury Hazards to Secretary's Pesticide Advisory Committee. U.S. Dept. Health, Educ., Welfare, November 1970: 1-97.

The problem of mercury contamination in the United States is potentially grave. This subject has been under intensive study for some years in Sweden and Finland where patterns of usage of mercury are similar to ours. The present situation stems from an extensive recent increase in industrial and agricultural uses of mercury. Methylmercury is concentrated several thousand times in fish and shellfish, partly through contamination of their food and partly through its presence in the water. The relative ease with which methylmercury passes the 'blood-brain barrier' accounts for severe neurologic manifestations. The sources of mercury contamination, which caused a recent poisoning disaster in Minamata Bay and Niigata, Japan, were discharges from plants using mercury catalysts in the manufacture of vinyl chloride and acetaldehyde. Methylmercury was preformed in the effluent of these factories. The report concludes with specific recommendations aimed at better understanding and solution of the mercury problem in the United States.

591. Anon. 1972. The effects of waste disposal in the New York Bight. Section 4. Finfish studies. Available from Nat. Tech. Inf. Serv., Springfield, Va., as Ad739 534: 1-24.

A study of the New York Bight was undertaken to determine the effects of sewage sludge on benthic fishes. Several sampling stations were selected for comparability of depth to Station 70, the designated sewage sludge disposal site. Groundfish were collected at frequent intervals in and beyond the area immediately affected by the sludge using two otter trawls which were towed for 15 minutes at 3 knots. Captured fish were sorted to species, counted and a subsample measured for total length. Identifiable stomach contents were enumerated by species whenever possible. Whole fish were frozen and sent to several laboratories for analysis of heavy metals and pesticides. Fish actively feed throughout the year in and around the area of sewage sludge disposal as evidenced by the ingested carbon-rich aggregate particles, 'band-aids', hair, and cigarette filters. Heavy metal analysis of fish collected in this area showed elevated levels of Ni, Cr, and Pb; in several fish the levels exceeded the standards of the Federal Water Pollution Control Administration (1968) designated as normals for marine animals.

592. Anon. 1972. Mercury in water - a bibliography. U.S. Office of Water Resources Research, Washington, D.C. Water Res. Sci. Infor. Cen., WRSIC 72-214.

This is a compilation of 195 abstracts for selected reports, journal articles, and various documents published mostly since 1967 on mercury in water. The abstracts include full bibliographical citations and a set of descriptors from the Water Resources Thesaurus.

593. Arnold, D.C. 1970. A tidal rhythm in the response of the barnacle, Balanus balanoides to water of diminished salinity. Jour. Mar. Biol. Assn. U.K. 50:1045-1055.

The response of adult barnacles to water of diminished salinity has been investigated on the shore under various tidal conditions. At each level studied some members of the population remained active at salinities of 21°/oo, but none responded when salinities were 18°/oo and lower. This responsiveness exhibits a rhythm closely related to the tidal cycle at the part of the shore investigated. This rhythm is sufficiently precise to ensure onset of responsiveness a few minutes prior to submersion under conditions where the time of exposure at successive low tides may vary from 0 to 2 1/2 hours.

594. Arnold, D.C. 1972. Salinity tolerance of some common prosobranchs. Jour. Mar. Biol. Assn. U.K. 52:475-486.

The responses of various common gastropods to waters of diminished salinities have been further investigated under experimental conditions, while earlier work on Patella has been extended. Differences in tolerance between limpets taken at high- and low-tide levels are not inherent in animals, but develop as they age, and are thus most marked in the largest individuals. Small specimens show a broad tolerance to waters of diminished salinity, regardless of the tide levels from which they have been obtained. Littorina spp. and Nucella also show a wide tolerance to diminished salinity, but this is not modified as the animals age and differences between high- and low-tide samples are not clear. Investigation of Littorina spp. in eastern Canadian waters has shown that there is some adaptation of different populations to salinities prevailing in particular sea areas. Gibbula is more demanding than other species studied, presenting a restricted tolerance to diminished salinity comparable to that developed by Patella settled at low-tide levels.

595. Aronson, A.L. 1971. Biologic effects of lead in fish. Jour. Wash. Acad. Sci. 61(2):124-128.

There is no evidence that lead constitutes a health problem to fish in the United States. But there is very little evidence on which to base any firm conclusion. Very few analytic data have been reported on concentrations of lead in fish in natural or experimental conditions. What data are available suggest that soluble lead is not present in natural waters of the United States in concentrations likely to be toxic to fish. There is no published evidence of any trend toward increased concentrations of soluble lead in natural waters. Much of the man-dispersed lead that is eventually washed into natural waters is probably precipitated owing to the presence of carbonates, hydroxides, and organic ligands in the water and settles to the bottom. There is no evidence that lead precipitated on the bottom of natural waterways is harmful to fish.

596. Arthur, J.W., and E.N. Leonard. 1970. Effects of copper on Gammarus pseudolimnaeus, Physa integra, and Campeloma decisum in soft water. Jour. Fish. Res. Bd. Canada 27(7):1277-1283.

Three invertebrate species were subjected to acute (96-hr), followed by long-term (6-week) copper exposures under continuous-flow bioassay conditions. Survival, growth, reproduction, and feeding were the responses used for measuring toxicant effects. The average 96-hr median tolerance limits (TLm) values for Campeloma decisum, Physa integra, and Gammarus pseudolimnaeus were 1.7, 0.039, and 0.020 mg/liter total copper, respectively. The total copper concentration having no effect after 6 weeks exposure for all three species was between 8.0 and 14.8 µg/liter. The newly hatched amphipods obtained from the second 6-week study were exposed to copper for 9 additional weeks, and grew to the adult stage only in copper concentrations $\leq$ 4.6 µg/liter. After 5 weeks exposure to a water system, survival of newly hatched Gammarus was markedly reduced when copper concentrations were between 12.9 and 6.2 µg/liter.

597. Aubert, M., R. Bittel, F. Laumond, M. Roméo, B. Donnier, and M. Barelli. 1972. Utilisation d'une chaine trophodynamique de type pélagique pour l'étude des transferts des pollutions métalliques. Rev. Inter. Océanogr. Médicale 28:27-52.

Factors affecting transfer of different metals at each level of a food chain which included diatoms (Diogenes sp. and Asterionella japonica), goldfish, and rats were measured. Factors evaluated included chelating and other complexing agents i.e. EDTA, ABS, humic acid and others. Five heavy metals: copper, zinc, chromium, lead and mercury in an ionic or complex form, were studied; the results are presented in tables.

598. Aubert, M., R. Bittel, F. Laumond, M. Roméo, B. Donnier, and M. Barelli. 1974. Utilisation d'une chaine trophodynamique de type néritique a mollusque pour l'étude des transferts des pollutants métalliques. Rev. Intern. Océanogr. Médicale 33:7-29.

Authors report on laboratory studies on transfer of selected metals within a neritic chain using molluscs. Five metals are considered: copper, zinc, chromium, lead and mercury, in an ionic form or associated with organic compounds, found in effluents and in oceanic environments. The results are discussed to assess the hazards of pollution presented by activation and chemical products.

599. Auerbach, S.I., and J.S. Olson. 1963. Biological and environmental behavior of ruthenium and rhodium. In Schultz, V., and A.W. Klement, Jr. (eds.), Radioecology. Reinhold Publ. Corp., New York: 509-519.

Many analytical and physiological data have been taken to imply a low biological availability of ruthenium and rhodium. Yet ruthenium-103 and Ru^{106} - Rh^{106} must be considered among the more important environmental contaminants because of their relatively high yield from fission and their moderately long half-lives.

Furthermore, because our knowledge of the biological and environmental behavior of the several complexes of ruthenium is meager, it is possible that the environmental mobility and hazards have been underestimated. Most experiments have utilized the valence III and IV states of ruthenium, whereas radioruthenium in waste effluents will be in more complex forms, depending upon the chemical composition of the waste and the environment.

Experiments involving waste effluents and nitrosyl compounds of ruthenium, which are formed in the common types of radioactive waste, have shown that these compounds may be taken up in greater quantities or behave differently when released into environmental situations. These differences in behavior which may be attributable to the various chemical forms of ruthenium impose a need for further investigations, particularly of a comparative nature, which take these complex forms into account. Examples are given using aquatic algae, higher plants, fishes, molluscs, annelids, mammals, and mosquitos.

Near industrial sources, levels of ruthenium radioisotopes may rise well above the levels contributed by atmospheric fallout, barring outbreak of nuclear war. While fallout levels have been too low to permit analyses of the chemical form of ruthenium present, increased levels due to resumption of weapons testing may present an opportunity for obtaining such information.

In the event of nuclear war, ruthenium radioisotopes could be one of the most significant contributors to gamma radiation from local and world-wide fallout during the first year or so following the detonation of nuclear weapons.

Regardless of origin, the instability of ruthenium compounds in changing environments will require the utmost care in interpretation of biological and environmental behavior of ruthenium.

600. Avargues, M., J. Ancellin, and A. Vilquin. 1968. Recherches expérimentales sur l'accumulation des radionucleides par les organismes marins. Rev. Intern. Océanogr. Médicale 11:87-99.

Results of laboratory and field studies on bioaccumulation of Cs-137, Ce-144, and Ru-106 by various marine species including pink shrimp, oyster, mussel, and clam are presented. These isotopes are present in radioactive wastes discharged from a plant located at the Hague.

601. Azam, F., B.B. Hemmingsen, and B.E. Volcani. 1973. Germanium incorporation into the silica of diatom cell walls. Archiv. Mikrobiol. 92(1):11-20.

A non-photosynthetic diatom, *Nitzschia alba*, two marine photosynthetic diatoms, *Cylindrotheca fusiformis* and *Cyclotella nana*, and a freshwater photosynthetic diatom, *Navicula pelliculosa*, were exposed to various ratios of Ge-68-labeled $Ge\ (OH)_4/Si\ (OH)_4$ (0.01, 0.1, or 1.0) in an attempt to trace the metabolic fate of Ge and to examine the possibility that Ge might follow the same metabolic pathway as Si. Cell counts, viability, Ge uptake and incorporation, isotope discrimination, silicic acid uptake, and effects of Ge on metabolism were determined. The diatoms took up labeled germanic acid from their growth media and incorporated up to 80% of it into the silica of their cell walls. Silicification appeared to be required for germanium incorporation. The uptake and incorporation of germanic acid was dependent upon the relative concentrations of Ge and Si. At Ge/Si ratios of 0.01, no inhibition of growth or of silicic acid uptake by *N. alba* was observed. The cell morphology was also normal and 60 to 80% of the Ge-68 taken up was incorporated. At Ge/Si ratios of 0.1, silicic acid uptake and growth of *N. alba* were inhibited by about 95%. Concomitantly, striking morphological aberrations occurred. Ten to 20% of the Ge-68 $(OH)_4$ taken up was incorporated. The possible use of labeled $Ge\ (OH)_4$ for the study of silicon metabolism is discussed.

602. Bachmann, R.W. 1963. Zinc-65 in studies of the freshwater zinc cycle. *In* Schultz, V., and A.W. Klement, Jr. (eds.), Radioecology. Reinhold Publ. Corp., New York: 485-496.

Author determined quantitatively some of the factors which affect distribution of zinc between water and various solid materials in lakes and also formulated a hypothetical model of the freshwater zinc cycle. Zinc-65 was used to measure uptake of zinc by suspensions of *Golenkinia paucispina*, organic detritus, lake sediments, and natural lake seston. It was also used to follow zinc uptake by *Daphnia pulex* and *Daphnia magna* in relation to presence of suspended materials. Artificial sediment-water systems were used to measure zinc uptake by lake sediments and to determine influence of mayfly nymphs *Ephemera simulans* on sediment penetration.

For all suspended materials tested, amount of zinc taken up at equilibrium could be related to zinc in solution using the Freundlich adsorption isotherm: $x = mkc^n$, where x is the amount taken up, c is the concentration in solution, m is the mass of adsorbent, and k and n are constants. Author found that zinc uptake decreased as concentrations of other cations in solution increased. The order of effectiveness of the respective ions in reducing zinc uptake by *Golenkinia* cells was $H^+ > Ca^{++} > Mg^{++} > Na^+ > K^+$. It was concluded *that these* organisms were accumulating zinc by means of an ion exchange type reaction. *Daphnia pulex* takes up zinc primarily by grazing on particles to which *zinc is* adsorbed rather than directly from solution; most of the zinc is lost on transfer to a fresh medium. More detailed investigations with *Daphnia magna* showed that a population of 100 animals per liter accumulated less *than* one percent of the total zinc available.

Oxidized sediments were found to remove as much as 96 percent of zinc added to the water above them, whereas reduced sediments would take up only about one-fifth as much. About 90 percent of the zinc taken up by such sediments did not penetrate deeper than 6 mm from the sediment surface. When mayfly nymphs were present, the zinc was mixed into the sediments and approached a uniform distribution. These nymphs did not accumulate a significant fraction of the zinc available. By use of the Freundlich equation, theoretical curves were derived to predict the zinc distribution between liquid and solid phases in lakes as a function of the total zinc content and the mass of suspended material present. A theoretical outline of the freshwater zinc cycle was presented which was characterized by exchanges between dissolved zinc and various organic and inorganic suspended materials as well as rooted aquatic plants and bottom sediments. The transfer of zinc to the sediments by the sedimentation of adsorbents is considered to be an important mechanism for the removal of the ion from lake waters. A net accumulation of zinc in the sediments should be the result. The formation of organic chelates and inorganic complexes are suggested as possible factors which may alter the scheme proposed.

603. Bagenal, T.B., F.J.H. Mackereth, and J. Heron. 1973. The distinction between brown trout and sea trout by the strontium content of their scales. Jour. Fish Biol. 5(4):555-557.

A method is described for distinguishing the scales of sea trout from brown trout by their strontium content. Scales of brown trout contain less than 200 μg of Sr/g and those of sea trout more than 300 μg of Sr/g.

604. Ball, I.R. 1967. The relative susceptibilities of some species of fresh-water fish to poisons-II. Zinc. Water Research 1:777-783.

The acute toxicity of zinc in a hard, well-aerated water to rainbow trout, perch, roach, gudgeon, and bream was determined over a period of 7 days. At all times trout were more sensitive than the cyprinid fish, and at the end of the test perch, roach, and bream showed similar sensitivities. The data confirmed that experiments of short duration are not necessarily reliable for ranking the ultimate sensitivities of several species of fish to a given poison.

605. Baptist, J.P., D.E. Hoss, and C.W. Lewis. 1970. Retention of chromium-51, iron-59, cobalt-60, zinc-65, strontium-85, niobium-95, indium-114m, and iodine-131 by the Atlantic croaker (Micropogon undulatus). Health Physics 18:141-148.

Evaluation of the possible effects of radioactive effluents on fisheries and, ultimately, the potential hazards to people requires a knowledge of the retention of radionuclides by fish. We measured retention of Cr-51, Fe-59, Co-60, Zn-65, Sr-85, Nb-95, In-114m and I-131 in croaker at ambient temperatures and salinities of local waters following single intraperitoneal injections. We also measured retention of Sr-85 and I-131 in various croaker tissues. Retention of all nuclides, except Co-60 and I-131, was expressed as two exponential rate functions. Cobalt-60 retention was expressed as a single rate function, and I-131 as three rate functions. Biological half-lives of long-lived components were as follows: Cr-51--70 days, Fe-59--215, Co-60--31, Zn-65--138, Sr-85--138, Nb-95--465, In-114m--224 and I-131--24 days. Effective half-lives of the same components were as follows: Cr-51--20 days, Fe-59--37.2, Co-60--30.5, Zn-65--88.3, Sr-85--44.2, Nb-95--32.6, In-114m--40.2 and I-131--6 days. It was concluded that fish containing large amounts of radionuclides with long effective half-lives, such as Fe-55, Zn-65 and Sr-90, may be hazardous to public health.

606. Barber, R.T., A. Vijayakumar, and F.A. Cross. 1972. Mercury concentrations in recent and ninety-year-old benthopelagic fish. Science 178:636-639.

Several species of bottom-dwelling fish from 2500 m with similar feeding habits had mercury concentrations that differed by an order of magnitude. With one species there was a correlation between size and concentration, with the larger individuals having mercury concentrations as high as 0.8 mg/kg (wet weight). The mercury content of the water in the deep-ocean habitat of these fish appears not to determine the mercury content of a particular fish; species-specific factors and size do appear to determine this concentration. The species-specific variation between the recent fish also existed between the same two species in specimens collected 90 years ago from a depth of 2000 m, and a 90-year-old specimen fits closely the size-concentration regression curve for nine recent individuals of the same species.

607. Barnes, H., and M. Barnes. 1974. The responses during development of the embryos of some common cirripedes to wide changes in salinity. Jour. Experim. Mar. Biol. Ecol. 15:197-202.

The effect of hypo- and hypersaline media on the development of barnacle embryos of *Balanus balanoides*, *B. crenatus*, *B. balanus*, *B. perforatus*, *Chthamalus stellatus*, and *Elminius modestus* has been examined. These species represent littoral and sublittoral, boreo-arctic and warm-temperate, relatively steno- and eurhyaline, and steno- and eurythermal forms. The range of salinity over which the embryos would develop to give free-swimming stage I nauplius larvae, no matter at what stage of development the cultures were started, was similar in all species, namely 15-20 to 40^{o}/oo. Low-salinity media cause cytolysis while high salinity media give grossly abnormal embryos which may, however, develop further. There seems little direct relation between salinity tolerance and that of the habitat in which the animals are found; a capacity for acclimation may be more important. The causes underlying the production of abnormalities are discussed.

608. Barth, L.J., and L.G. Barth. 1974. Effect of the potassium ion on induction of notochord from gastrula ectoderm of *Rana pipiens*. Biol. Bull. 146(3):313-325.

Small aggregates of cells prepared from explants of ventral ectoderm of frog gastrula were treated for 3-4 hrs in 71 mM Li^+ added to standard solution. When cultured in standard solution containing 1.3 mM K^+, the aggregates of ventral ectoderm cells differentiated into nerve and pigment cells. As the K^+ concentration in the culture medium was raised through 2.3, 3.3 and 5.3 mM, the frequency of pigment cells declined and networks of vacuolated cells were formed, which later fused to form small notochordal masses. Raising the K^+ to 7.3 and 9.3 mM gave nerve and pigment cells again, as in the lower potassium concentrations. The effect of high K^+ on lithium-induced cells becomes irreversible during the first 18 hrs. Cells may be returned to 1.3 mM K^+ after 18 hrs and notochord differentiation will occur.

Induced notochord cells first appear as somewhat larger cells which become filled with very small vacuoles by 7-8 days of culture. These small vacuoles then coalesce to form larger and larger vacuoles (9-12 days). The vacuolated cells aggregate into small clumps. Cultures were fixed and stained at various intervals for photography.

Cultures of small explants of notochord in 5.3 mM K^+ were observed to undergo the same type of differentiation. In both cases the notochord cells and vacuoles were smaller than in the whole embryo. Larger explants of notochord from archenteron roof gave large masses of notochord cells about the same size as in the whole embryo. When lithium-treated aggregates of the ventral ectoderm were fused together in 5.3 mM K^+ to form a composite of 10-15 aggregates, the notochordal masses were larger and the notochord cells were about the same size as obtained in comparable size explants of notochord from the roof of the archenteron.

These findings are discussed in relation to the effects of high potassium on membrane depolarization, protein synthesis; DNA synthesis, and increase in intracellular Ca^{2+}.

609. Bashamohideen, M., and V. Parvatheswararao. 1972. Adaptations to osmotic stress in the fresh-water euryhaline teleost _Tilapia mossambica_. IV. Changes in blood glucose, liver glycogen and muscle glycogen levels. Marine Biology 16:68-74.

Osmoregulation energetics in _Tilapia mossambica_ acclimated to media of different salinities, were studied. In stress media (75 and 100% sea water), blood glucose increases significantly accompanied by a corresponding increase in oxygen consumption and cytochrome-oxidase activity, suggesting that oxidative degradation of blood glucose is the predominant energy source for osmotic work in these stress media. It is likely that variations in blood-glucose level as a function of acclimation to the heterosmotic media are governed by the combined effects of salinity of the medium and blood-medium osmotic gradient, rather than by effect of any one of them separately. Depletion of muscle glycogen at significant levels is noticed only in stress media. Presumably, there is an augmentation of oxidative metabolism with glycolysis to meet the exacting energy demands for heavy osmotic work in high stress media. Prior acclimation to 75% sea water (24.37°/oo) facilitates subsequent acclimation to 100% sea water (32.50°/oo) with less energy cost--an instance of "facilitation acclimation." Smaller individuals of _T. mossambica_ osmoregulate with less energy expenditure than larger ones. Thus, smaller individuals are osmotically more efficient.

610. Batte, E.G., L.E. Swanson, and J.B. Murphy. 1951. New molluscicides for the control of fresh water snails. Amer. J. Vet. Res. 12(43):158-160.

A total of 33 compounds was tested for molluscicidal activity against lymnaeid snails; however, only copper sulfate and dinitro-o-cyclohexylphenol killed 100 percent of the test snails at a concentration of 1 mg/l in twenty-four hours. Other compounds in the dinitro and chlorophenate series have shown promise and will be tested and compared with copper sulfate.

611. Beamish, F.W.H. 1970. Influence of temperature and salinity acclimation on temperature preferenda of the euryhaline fish Tilapia nilotica. Jour. Fish. Res. Bd. Canada 27(7):1209-1214.

When Tilapia nilotica was acclimated to temperatures of 15-35°C and salinities of 0-30°/oo in a vertical gradient tank, maximum temperature preferenda occurred at acclimation temperatures of 20 and 25°C irrespective of salinity. Preferenda declined as acclimation temperature was increased above 25°C and, except at 0 and 7.5°/oo, declined as acclimation temperature was decreased below 20°C. The pattern of relation between final temperature preferenda and salinity was similar to that reported between oxygen consumption for a given sustained swimming speed and salinity. The final preferendum was lowest at 15°/oo, close to the isosomotic salinity of T. nilotica, and highest at the extremes, 0 and 30°/oo. Final temperature preferenda are in general agreement with optimum temperatures reported for growth, reproduction, and swimming performance.

612. Beasley, T.M. 1969. Lead-210 in selected marine organisms. Ph.D. Dissertation, Oregon State Univ., Corvallis, Ore.: 1-82.

The results of the present research represent a first approximation to general levels of ^{210}Pb which occur in some surface and benthonic organisms of the oceanic environment. Reasonable correlations exist between inputs of ^{210}Pb by precipitation and concentrations of this isotope in organisms residing in the upper 100 meters of the ocean. This effect quickly subsides, however, in organisms living at greater depths. Mechanisms for this decrease have been proposed, yet measurement of this isotope in fishes living at intermediate depths would help clarify the trend.

Polonium-210 appears to be the major contributor of radiation dose to marine organisms from internal sources although other isotopes not measured here (^{226}Ra, ^{228,230}Th, etc.) might also contribute significantly to the dose of the biota. Variations which were observed in

^{210}Pb concentrations in marine organisms would undoubtedly be reflected by similar variations in ^{210}Po concentrations, but even so it is quite possible that the radiation dose rate from this isotope alone would exceed the dose rate from both cosmic ray radiation and ^{40}K.

The presence of ^{210}Pb and ^{210}Po in marine organisms that now serve as food for humans and the contemplated use of marine concentrates which might contain significant quantities of these isotopes should be of interest to health physicists. Although levels of these isotopes are far below those which would constitute a radiological hazard, continued use of such products could well result in the ^{210}Pb-^{210}Po pair becoming the major source of the skeletal radiation dose, which is not the case today. Perhaps equally important are the quantities of stable lead and other trace metals which might be present in various protein concentrates, and which would cause a departure from the "normal" dietary intakes which the general population experiences today.

613. Beasley, T.M. 1971. Mercury in selected fish protein concentrates. Environ. Sci. Technol. 5:634-635.

Levels of mercury in fish protein concentrates (FPC) have been measured. Concentrates prepared from surface feeding fishes taken from different locales contained 0.3 to 0.9 mg/kg mercury. These concentrations appear consistent with the known enrichment factors which occur in the chain: water-fish-concentrate.

614. Beasley, T.M., and E.E. Held. 1971. Silver-108m in biota and sediments at Bikini and Eniwetok Atolls. Nature 230(5294): 450-451.

Authors found ^{108m}Ag in biota and sediments collected at previous nuclear testing sites in the Pacific. The radionuclide was first detected in a composite sample of hepatopancreases from spiny lobsters collected at Bikini Atoll in 1969; subsequently authors measured its concentrations in several samples from Bikini and Eniwetok Atolls. Concentrations of ^{108m}Ag in the hepatopancreas of spiny lobsters taken from Bikini with Eniwetok shows that the Bikini specimens contain 2 to 3 times more ^{108m}Ag. By contrast, the concentration of ^{108m}Ag in the composite sample from Eniwetok is less than that in a lobster specimen from Guadalupe. All values reported ranged between 0.20 and 1.1 d/m/g dry wt.

615. Beasley, T.M., E.E. Held, and R.M. Conard. 1972. Iron-55 in Rongelap people, fish and soils. Health Physics 22:245-250.

The ^{55}Fe body burdens for 60 residents of Rongelap Atoll are reported. The measured burdens are approximately 3 times higher than those of a similar number of residents from Tokai-mura, Japan. Prominent in the Rongelap diet are the reef fishes: goat fish (*Mulloidichthys* sp.), mullet (*Neomyxus* sp.) and surgeon fish (*Acanthurus* sp.). Since previous measurements in 1966 revealed substantial ^{55}Fe body burdens in Japanese residents, the current Rongelapese ^{55}Fe body burdens pose interesting questions.

616. Beasley, T.M., T.A. Jokela, and R.J. Eagle. 1970. Radionuclides and selected trace elements in marine protein concentrates. Available from Nat. Tech. Infor. Ser., Springfield, Va., as RLO-2225-T-14-2: 1-15.

Consumption of 10-30 g/day of concentrates prepared from surface feeding fishes would substantially increase intake of Pb-210, Po-210, and stable Pb, Co, and Ag. The stable Pb is attributed largely to automotive exhaust pollution of surface waters. It is uncertain whether Ag, Co, Cd, and Cu are derived solely from ecological concentration processes since contamination may occur during processing. Sr-90 in the concentrates was less than 0.05 d/m/g of dry weight.

617. Beasley, T.M., and H.E. Palmer. 1966. Lead-210 and polonium-210 in biological samples from Alaska. Science 152:1062-1063.

The naturally occurring concentrations of lead-210 and polonium-210 in certain biological samples from Alaska, including salmon, butterfish, whitefish, seal muscle, seal liver, and polar bear meat, are unusually high. The concentration processes are similar to those observed for artificially produced radioactive fallout. Concentrations of these nuclides are greater in Alaskan natives than they are in other United States residents.

618. Ben-Bassat, D., G. Shelef, N. Gruner, and H.I. Shuval. 1972. Growth of *Chlamydomonas* in a medium containing mercury. Nature 240(5375):43-44.

A pure culture of *Chlamydomonas reinhardi* y (-1) was grown on a sterile medium containing acetate, citrate, and minerals. Mercury at various concentrations was provided as $HgCl_2$ or $Hg(203)Cl_2$. Both compounds caused similar effects; at mercury concentrations up to 1.0 mg/l, an increasing lag period occurred, but cells were able to recover from the growth lag. Growth in cultures containing 2 mg/l mercury was completely retarded. The mercury concentration in a control of medium with no cells decreased by 5%. In the whole culture it decreased by 40% over the same 8 day period. The cells contained 2-2.5% of the total culture radioactivity. The amount of mercury per cell decreased by 90% from the 2nd to the 8th day. In the same period the total mercury of the culture decreased by 30%. Most of the loss of mercury is a direct outcome of the presence of algae in the medium and the process was particularly active during the lag period. This phenomenon may be due to a biological process causing a change in the mercury to a form which is volatile and less permeable or has less affinity to the cells.

619. Besch, K.W., and P. Roberts-Pichette. 1970. Effects of mining pollution on vascular plants in the northwest Miramichi River System. Canadian Jour. Botany 48:1647-1656.

Effects of copper-zinc mining pollution on riparian and aquatic vascular plants were studied in the Northwest Miramichi River system of northern New Brunswick. After a period of 8 years, the riparian vascular flora of the river system's gravel shores has been completely eliminated or seriously reduced. The most sensitive plants are the submersed aquatic species, followed by riparian dicotyledons. Monocotyledons are less sensitive than dicotyledons and *Equisetum arvense* is the least susceptible species. A rough index of pollution severity was devised based on the absence of species or species groups which would normally be present under unpolluted conditions. The absence of some spring-flowering geophytes normally present at the high-water line is believed to be caused by the large amounts of toxic metals accompanying the high spring flows. It is possible to distinguish three different degrees of severity of zinc-copper pollution in rivers and streams, according to the effects on the higher vascular flora. With extremely high pollution, trees and shrubs along the banks are killed; with medium to high pollution only a few species are present. With low pollution only submerged vascular plants are eliminated.

620. Betzer, S.B., and M.E.Q. Pilson. 1974. The seasonal cycle of copper concentration in *Busycon canaliculatum* L. Biol. Bull. 146(2):165-175.

Individual tissues of approximately 100 whelks (gastropods) were analyzed for copper content. Tissue copper concentrations showed a high degree of individual variation, but seasonal trends were evident. In the digestive gland, the organ with the highest copper concentration, the mean monthly concentrations were about 5 to 10 times higher in the summer (400-900 μg Cu/g fresh weight) than in the winter (65-120 μg Cu/g). Gut concentrations followed the same seasonal trend. The copper concentration in the gonad increased in the early spring and then decreased in the late spring and summer to low fall and winter values. The total copper in the gonad increased 6-fold during the spring and summer, however, because of large increases in size as late summer spawning approached. The total copper in the gonad dropped off after the spawning season. Monthly average blood copper and protein concentrations followed the same seasonal pattern as the digestive gland and gut, with copper ranging from a monthly average of 42 μg/ml in February to 175 μg/ml in June. Nearly all the blood protein present was hemocyanin, and there was no apparent seasonal change in the ratio of copper:protein. The copper concentration of the kidney was similar to that of the blood during most of the year, but in late summer and fall it increased to a maximum (171 μg/g in Oct.), while that of the blood and other tissues was decreasing. Whelks in Narragansett Bay usually begin to feed in late May or early June; the general early summer increases in the copper concentration of most tissues correlated with this commencement of feeding.

621. Beyenbach, K.W. 1974. Magnesium excretion by the rainbow trout, *Salmo gairdneri*. Ph.D. Dissertation, Washington State Univ., Pullman, Wash.

Magnesium is transported from blood to urine in marine teleosts. An inverse relationship has been noted between urinary magnesium and sodium concentrations, which may be due to the coupling of Mg secretion to Na reabsorption through a common tubular transport system, or coupling may be indirect. This study was to find evidence for the tubular exchange of Mg for Na in rainbow trout, *Salmo gairdneri*. Renal clearance studies were conducted in trout that were adapted to fresh water (FW), half-strength sea water (1/2SW), and full-strength sea water (SW), and ureteral Na-Mg relationships were examined over a wide range of Mg excretory rates.

Results from control and Mg-infused fish do not support tubular Na/Mg exchange. Analyses of ureteral urine reveal that Mg and Na concentrations are not inversely related in SW trout. In addition, ureteral Mg and Na excretion rates are directly related, and rates of Na reabsorption and Mg secretion in control and Mg-infused trout show no clear, positive, stoichiometric relationship as might be expected from an obligatory 2:1 or 1:1 exchange.

In contrast, when ureteral urine was allowed to remain in the urinary bladder of SW-adapted trout, analyses of residual bladder urine revealed inverse relationships between Na and Mg concentrations. In residual bladder urine, Na concentrations (9.88 mEq/liter) were approximately 10X lower than in ureteral urine (101.3 mEq/liter) whereas Mg concentrations were consistently higher in bladder urine (bladder urine: 175.4 mEq/liter; ureteral urine: 138.2 mEq/liter). It was concluded that bladder reabsorption of H_2O with Na may concentrate Mg and in this way generate the inverse relationship between Na and Mg concentrations. Thus, Mg is secreted by the renal tubule, Na and H_2O appear to be reabsorbed by the urinary bladder, and the coupling between Mg secretion and Na reabsorption is indirect at proximal and distal sites.

Additional studies suggest that trout reabsorbs Mg in FW, but secretes the ion in 1/2SW and SW. The infusion of Mg in SW-adapted fish causes a diuresis which persists until plasma Mg concentrations return to normal (2.6 mEq/liter); ureteral Mg excretory rates may reach 480 μEq/kg-hr. In control and experimental trout changes in the rates of ureteral Mg excretion are accompanied by parallel changes in Na excretion. Rate of tubular urine flow may confer this parallelism between Mg and Na excretion. Urine flow rate may in turn depend on the excretion rate of the dominant tubular osmotic solute: in control SW fish ureteral urine flow rate correlates to Na excretion rate, whereas in Mg-infused fish, rates of Mg excretion and urine flow are directly related. Ureteral pH is slightly alkaline (7.15) in control, but acidic (6.59) in Mg-infused SW trout.

622. Beyerle, G.B., and J.E. Williams. 1967. Attempted control of bluegill reproduction in lakes by the application of copper sulfate crystals to spawning nests. Progr. Fish-Cult. 29(3): 150-155.

Application of copper sulfate did not kill measurably more bluegills than would have died normally during this period. Certainly it did not eliminate enough fish to cause any drastic change in bluegill growth. Authors did not approach their goal of eliminating all the young bluegills in the treated lakes. In fact, they collected more bluegills in the treated lakes after treatment than in the preceding year.

Attempts to control the size of an entire bluegill year class in four lakes by applying copper sulfate to bluegill nests required considerable effort continuously by four men for almost 3 months. Even if the treatments had been effective, the effort involved would make this control method of questionable value as a general management procedure for lakes, especially since annual treatments probably would be necessary to prevent a compensating high survival rate in subsequent generations of bluegills. It is possible that bluegill reproduction could be controlled with copper sulfate in ponds and small lakes that have well-defined, easily located spawning areas. However, great care must be taken to locate and treat all nests semi-weekly during the spawning season. The number of young produced on a few untreated nests could overpopulate a small body of water.

623. Bhatt, Y.M., V.N. Sastry, S.M. Shah, and T.M. Krishnamoorthy. 1968. Zinc, manganese and cobalt contents of some marine

bivalves from Bombay. Proc. Nat. Inst. Sci., India, pt. B, Biol. Sec. 34(B,6):283-287.

Levels of zinc, manganese, and cobalt were determined in the soft parts of six species of marine bivalves to study their suitability as "indicator organisms" for the radioisotopes of these elements in sea-water. It is found that the oyster, *Crassostrea gryphoides* accumulates zinc from sea-water by factors ranging from 5,500 to 13,000 and may be utilized as an indicator for radioisotopes of zinc in sea-water. Likewise, the clam, *Sunetta donacina*, shows a high affinity for manganese and may be used for a similar purpose in the study of contamination of sea-water by radioisotopes of manganese. The concentration factors for cobalt in these bivalves range from 30 to 1,730; and, among the species studied, no suitable indicator for cobalt was noticed.

624. Biebl, R., and C.P. McRoy. 1971. Plasmatic resistance and rate of respiration and photosynthesis of *Zostera marina* at different salinities and temperatures. *Marine Biology* 8:48-56.

Zostera marina L. was studied at the Izembek Lagoon, Alaska Peninsula. Two morphologically different forms, tidepool and subtidal, can be distinguished. Both show a high tolerance to different salinities and temperatures. The plasmatic resistance was found in a range of distilled H_2O up to 3.0 sea water (24 h) and between -6° and 34°C (12 h). Within these resistance limits, the photosynthesis, which has its maximum in normal (1.0) sea water, decreases nearly to zero not only in distilled H_2O but even in 2.0 sea water, and increases with the temperature in the tidepool form up to 35°C, but in the subtidal form up to 30°C only. At higher temperatures photosynthesis declines sharply in both forms. Respiration has its minimum in distilled H_2O and at 0°C and increases with increasing salinity and temperature.

625. Biesinger, K.E., R.W. Andrew, and J.W. Arthur. 1974. Chronic toxicity of NTA (nitrilotriacetate) and metal-NTA complexes to *Daphnia magna*. Jour. Fish. Res. Bd. Canada 31:486-490.

The chronic toxicity of NTA tested as the trisodium salt, to *Daphnia magna* in eight natural waters varied tenfold. A strong negative correlation (r = 0.95) between water hardness and NTA toxicity was found; NTA was most toxic at 438 mg/l hardness and least toxic at 22 mg/liter. The 21-day LC50 in all cases closely approximated the calculated molar equivalence point of total hardness and NTA. Bioassay experiments of NTA, with copper and zinc added, confirmed earlier reports that chelates of copper and zinc with NTA are relatively nontoxic. The solutions were toxic only when the metals or NTA were present in excess. The toxicity of iron (III) was not appreciably changed by NTA chelation.

626. Biesinger, K.E., and G.M. Christensen. 1972. Effects of various metals on survival, growth, reproduction, and metabolism of *Daphnia magna*. Jour. Fish. Res. Bd. Canada 29(12):1691-1700.

The toxicities of various metals to *Daphnia magna* were evaluated on the basis of a 48-hr 50% lethal concentration (LC50), a 3-week-LC50, and a 16% decrease in the number of young born (reproductive impairment). The 3-week 16% reproductive impairment concentrations (in mg per liter) for the metal ions tested were: Na, 680; Ca, 116; Mg, 82; K, 53; Sr, 42; Ba, 5.8; Fe, 4.38; Mn, 4.1; As5+, 0.520; Sn, 0.350; Cr3+, 0.330; Al, 0.320; Zn, 0.070; Au, 0.060; Ni, 0.030; Pb, 0.030; Cu, 0.022; Pt, 0.014; Co, 0.010; Hg, 0.0034; and Cd, 0.00017. At metal concentrations permitting survival but impairing reproduction, daphnids weighed less than control animals. Amounts of total protein and glutamic oxalacetic transaminase activity varied with the different metals. The negative logarithm of the solubility product constant of the metal sulfides, electronegativity, and the logarithm of the equilibrium constant of the metal-ATP complex were positively correlated with toxicity to *D. magna*. Other physicochemical properties were considered, but no additional correlations were found.

627. Bilinski, E., and R.E.E. Jonas. 1973. Effects of cadmium and copper on the oxidation of lactate by rainbow trout (*Salmo gairdneri*) gills. Jour. Fish. Res. Bd. Canada 30(10):1553-1558.

At the highest Cd concentration (11.2 mg/l), fish died in 7 hr. At 1.12 mg Cd/l, mortality was 50%; of the fish surviving at 96 hr, oxidative activity of gills was inhibited by 50%. All fish died in 24 hr when exposed to the highest level of copper (0.636 mg/l). At a concentration of 0.064 mg Cu/l, 50% died; of those surviving, oxidative activity was inhibited 53%. Comparatively high levels of cadmium (20 micrograms) or copper (50 micrograms) were needed to produce in vitro inhibition of lactate oxidation by gill filament. Histological studies suggest that impairment of oxidative activity might be due to disruption of cellular organization or to inhibition of enzyme activity. The lactate oxidation test appears to be useful only at high levels of Cd and Cu, however, it could be useful in detecting gill damage with other toxicants.

628. Black, W.A.P., and R.L. Mitchell. 1952. Trace elements in the common brown algae and in seawater. Jour. Mar. Biol. Assn. U.K. 30(3):575-584.

Some common Scottish Laminariaceae and Fucaceae have been analyzed spectrographically, and Co, Zn, Fe, Ni, V, Rb, Mo, Ti, Li, Pb, Cr, Ba, Sn, Ag, Sr, Mn determined. The results show a seasonal variation, and also considerable diversity in elemental content in different species taken from the same habitat. With the Laminariaceae the trace elements are more concentrated in the perennial stipe than in the attached frond, and are generally less than in the Fucaceae. Samples of sea water taken off Plymouth and the West Coast of Scotland have also been analyzed spectrographically and fourteen of the minor elements determined. Concentration factors are given showing the extent to which marine algae can accumulate the trace elements. Values of over 1000-fold concentration are reported. Fucus spiralis, for example, contains 10,000 times more titanium than the surrounding sea water.

629. Blaustein, M.P., and A.L. Hodgkin. 1969. The effect of cyanide on the efflux of calcium from squid axons. Jour. Physiology, London 200:497-527.

This account reports on effect of cyanide and external ions on efflux of calcium from axons. Cyanide had little immediate effect on calcium efflux, but after 1 1/2 h efflux rose from 5 to 15 times its normal value. The effect was rapidly reversed when cyanide was removed. The extra efflux in cyanide seemed to be largely an exchange for external calcium and sodium since it was abolished by replacing Ca with Mg and Na with Li. Removal of Ca reduced the Ca efflux in cyanide to 1/3 and subsequent removal of Na reduced it to between 1/10 and 1/20. A possible explanation of the cyanide effects is that calcium ions are released from a store and can then exchange with Ca and Na in the external medium. Evidence for an increase in free calcium was that pretreatment with cyanide greatly increased the rate at which Ca-45 could be dialysed from axoplasm. The experiments provide evidence for coupling between Na influx and Ca efflux and suggest that downhill movement of Na may give some of the energy for extruding Ca. In the appendix theoretical equations for diffusion and chemical reaction are used to calculate the time course of Ca efflux following an axial injection.

630. Bligh, E.G. 1972. Mercury in Canadian fish. Jour. Inst. Can. Science et Technol. Aliment. 5(1):A6-A14.

Japanese and Swedish experiences with Hg pollution are reviewed. Some highlights of the Canadian national survey on Hg contamination are presented including type of fish, location and Hg content. Industrial sources that may be contaminating waters and the incorporation of Hg contaminated fish into animal feeds are considered.

631. Boon, D.D. 1973. Iron, zinc, magnesium, and copper concentrations in body meat of the blue crab, Callinectes sapidus.

Chesapeake Science 14(2):143-144.

Average concentrations of selected metals, in mg/kg wet wt, for body meat were: 21 for Fe; 46 for Zn; 466 for Mg; and 19 for Cu.

632. Boothe, P.N., and G.A. Knauer. 1972. The possible importance of fecal material in the biological amplification of trace and heavy metals. Limnology and Oceanography 17(2):270-274.

The concentrations of As, Cd, Co, Cr, Cu, Fe, Mn, Pb, and Zn in a brown alga, Macrocystis pyrifera, and in fecal material of the crab Pugettia producta fed exclusively on M. pyrifera were measured by atomic absorption spectroscopy. In this closed system of a primary producer and a primary consumer, the concentration of these elements in the resulting feces of the consumer was determined. Except for Cr and Cd, whose concentrations in the fecal material were less than in the kelp, all other elements showed levels in the feces 2.3-14 times those in the algae. Fecal material thus may play a significant role in the cycling of elements in the marine environment.

633. Boroughs, H. 1958. The metabolism of radiostrontium by marine fishes. Proc. Ninth Pacific Sci. Congr. 16:146-151.

Strontium is rapidly absorbed from the gut and transported by the plasma throughout the entire fish body. Within a day, only a few percent of the dose remains within the body. Of the strontium remaining, the bulk of it is associated with the bones, integument and gills, which of course contain both bone and cartilage.

634. Boulton, P., and L.J. Hetling. 1972. A statistical analysis of the mercury content of fresh water fish in New York State. N.Y. State Dept. of Environ. Conservation, Tech. Paper No. 19:1-16.

Because of the concern for mercury concentrations in the fish in New York State, more than 3200 fish from 142 locations were analyzed for mercury by atomic absorption. The average mercury level for all fish was 0.44 mg/kg and the highest level found was 8.20 mg/kg in fish from Onondaga Lake. Excluding the findings for Onondaga Lake, the maximum concentration found was 3.40 mg/kg.

635. Braham, H.W. 1973. Lead in the California sea lion (Zalophus californianus). Environ. Pollut. 5:253-258.

Lead in nineteen organs from California sea lions was determined by atomic absorption. Lead accumulated in significantly higher concentrations in hard tissues, such as bone and teeth, than in soft tissues, such as fat and muscle. Comparable results are found in man, suggesting that exposure levels of lead may be similar for terrestrial and coastal environmental communities.

636. Branca, G., F. Breuer, A.A. Cigna, and R. Amavis. 1973. Applications of a derived formula for the discharge of radioactive liquid wastes. Report EUR 4897e: 35 p. Available from Nat. Tech. Infor. Ser., Springfield, Va., as EUR-4897e.

Discharge limits (in curies/year) to a typical aquatic receiving environment for radioisotopes from nuclear power stations are calculated for exposure pathway via consumption of lake fish (Sr-90, 0.68; Cs-137, 5; Ru-106, 370; and Co-60, 128) and drinking water (Ru-106, 90; others higher than for fish consumption). Concentration factors for radioisotope uptake by fish for these and other elements (tritium, Ce, Pu, Mn, Fe, Co), and discharge limits for other aquatic receiving environments are tabulated.

637. Brereton, A., H. Lord, I. Thornton, and J.S. Webb. 1973. Effect of zinc on growth and development of larvae of the Pacific oyster Crassostrea gigas. Marine Biology 19(2):96-101.

Following the observation of periodic high concentrations of zinc in estuarine waters used in the White Fish Authority's oyster hatchery at Conway, North Wales, studies were conducted on effect of zinc on larvae of Crassostrea gigas. Zinc, added to sea water both as zinc sulfate and as a natural mine-adit water, was applied for a period of 5 days, after which larvae were maintained for a further 5 days in sea water alone. Increasing concentrations over the range 125 to 500 µg/l of Zn resulted in decreasing growth and increasing incidence of abnormality and larval mortality. A second trial with zinc sulfate showed 50 µg/l of Zn to have little effect on larval development, a progressive decrease in growth at 100 and 150 µg/l, and no growth at 200 µg/l. It is suggested that the deleterious effect of short-term exposure to zinc may well have contributed to the intermittent failure of larvae and irregular productivity recorded at the hatchery. It is also possible that zinc contamination in estuaries may affect natural oyster breeding, and may have to be considered in the future siting of hatcheries for seed production.

638. Brooks, R.R., and M.G. Rumsby. 1965. The biogeochemistry of trace element uptake by some New Zealand bivalves. Limnology and Oceanography 10:521-527.

Spectrographic determinations of Ag, Cd, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Sb, V, and Zn were carried out on three species of New Zealand bivalves. Analyses were performed on the sediment, on the whole animals excluding shells, on the shells, and on the individual dissected organs. All the elements concerned showed more enrichment in the shellfish than in the marine environment. Conclusions have been reached concerning the geochemical and biochemical processes involved in trace element uptake by the biosphere.

639. Brooks, R.R., and M.G. Rumsby. 1967. Studies on the uptake of cadmium by the oyster, Ostrea sinuata (Lamarck). Austral. Jour. Mar. Freshwat. Res. 15:53-61.

In order to study elution and displacement of adsorbed ions into filtered sea water and their displacement by adsorbed Cd, analyses for Cd, Ag, Mn, Pb, V, and Zn were carried out on freshly killed oysters, specimens maintained for 100 hr in filtered sea water and on a further number treated for the same period with filtered sea water containing 50 mg/l of Cd. Although a high Cd concentration did not appear to displace other ions, there was some evidence for loss of ions from the visceral mass. Concentrations in oysters equilibrated with sea water containing added Cd, indicated that this element was strongly accumulated within gills, viscera, and heart. These findings were confirmed in radiometric experiments involving uptake of $^{115/115m}$Cd from sea water containing this radionuclide. These experiments were also used to measure the rate of uptake of Cd which although relatively slow, was appreciable in magnitude. Fractionation factors for the various organs for varying Cd concentrations in sea water showed a very similar pattern for all organs studied and indicated cessation of uptake at Cd concentrations between 40 and 140 mg/kg. It was concluded that uptake was due to unselective adsorption probably by coordination to organic ligands. This theory was strengthened by radiometric experiments on the oyster heart where proteinbound Cd probably did not exceed 25% of the total.

640. Brooks, R.R., and D. Rumsey. 1974. Heavy metals in some New Zealand commercial sea fishes. New Zealand Jour. Mar. Freshwat. Res. 8(1):155-166.

To establish a base line against which future pollution may be measured, eight common commercial species of New Zealand sea fish were analyzed for cadmium, chromium, copper, iron, lead, manganese, nickel, and zinc. One sample of edible muscle tissue was analyzed for each of 70 samples of each species. The internal organs of up to five specimens of each species were also analyzed.

None of the edible parts of the fish appeared to have trace element levels likely to be a public health problem: cadmium 0.002-0.02 mg/kg, chromium 0.01-0.04, copper 0.04-0.95, iron 0.9-13.5, lead 0.14-0.95, manganese 0.04-2.00, nickel 0.01-0.08, zinc 2.0-36.0. However, some organs, particularly the liver, had relatively high concentrations of elements such as cadmium (up to 54 mg/kg). Only if some industry were to seek to exploit internal organs of fish for human consumption would such levels become important. There was some evidence for a relationship between trace element concentrations and fish size for copper in 2 species, iron in one species, manganese in another, and for zinc in 2 species. Some element pairs such as copper and zinc, iron and manganese, appeared to have concentrations which were mutually related. It was assumed that the elemental concentrations reported represent natural levels and are not the result of significant man-made pollution because there are no major industries or large urban centers adjacent to the fishing grounds.

641. Brouse, D.D. 1966. Copper sulphate air spray cures lake algae problem. Water and Pollution Control 104(4):25-27.

Since 1960, Sudbury, Ontario, bordering Lake Ramsey, has twice experienced severe taste and odor problems in its municipal water supply. Lake Ramsey has a surface area of 2,023 acres, depths to 65 feet, and little outflow. In October 1965, the algae count peaked at 33,400 areal standard units, Aphanizomenon predominating, accompanied by a threshold odor number 200. Aphanizomenon's ability to withstand winter temperatures necessitated immediate action. On November 6-8, cropdusting aircraft sprayed 20 tons of copper sulfate over the lake surface resulting in copper content of 0.20 mg/l. The immediate area of municipal water intake was avoided. By November 14th, the algae count had been reduced to 2,500 and the odor number to 24. On November 22nd, the algae count had rebounded to 5,000 and odor number to 140, while the copper concentration remained 0.20 mg/l. In late November, a second treatment brought the maximum average copper concentration to 0.36 mg/l. One week later, after freezing over, the lake's algae count was back down to 2,000 and the odor number to 17. By the end of December, the water was satisfactory for municipal use with only slight noticeable odor (Algae count: 1,300, odor number: 4).

642. Brown, B.E., and R.C. Newell. 1972. The effect of copper and zinc on the metabolism of the mussel Mytilus edulis. Marine Biology 16:108-118.

The effects of copper and zinc on the metabolism of the mussel Mytilus edulis (L.) and its component tissues were studied. 500 mg/l copper sodium citrate inhibited oxygen consumption of the whole animal and gill tissue, but no similar effect was observed on digestive gland tissue. 500 mg/l zinc sodium citrate exerted no effect upon gill or digestive gland respiration, and neither metal salt affected the respiration of homogenates of gill, digestive gland, or gonad. Direct observation of gill tissues during exposure to the metals revealed that 500 mg/l copper sodium citrate caused inhibition of ciliary activity; exposure of tissues to 2 mg/l Cu for 24 h resulted in only partial inhibition of the cilia. It is suggested that metabolic suppression noted in whole animals and gill tissues is due to the inhibition of an energy-consuming process such as ciliary activity rather than interference with respiratory enzyme systems.

643. Brown, V.M., and R.A. Dalton. 1970. The acute lethal toxicity to rainbow trout of mixtures of copper, phenol, zinc and nickel. Jour. Fish Biol. 2:211-216.

The acute lethal toxicities to rainbow trout, Salmo gairdneri Richardson, of mixtures of copper and phenol, of copper, zinc and phenol, and of copper, zinc and nickel, over an exposure period of 48 h were determined. The concentrations selected for testing were such that each poison theoretically contributed equally to the toxicity of the mixture. It was found that the toxicities of these mixtures could be adequately predicted by summation of the fractional toxicities of the particular poisons which were present.

644. Brown, V.M., D.H.M. Jordan, and B.A. Tiller. 1969. The acute toxicity to rainbow trout of fluctuating concentrations and mixtures of ammonia, phenol and zinc. Jour. Fish Biol. 1:1-9.

Concentrations of ammonia, zinc, and ammonia plus zinc, which were lethal to 50% of a batch of trout within 48 hours were similar, whether fish were immersed in constant concentrations of poisons or in concentrations fluctuating within ±50% of the 48-hour LC50 at equal intervals of time, as long as the periodicity of the fluctuations did not exceed the resistance time for the particular poison involved. Except when zinc predominated in a mixture, the fractional toxicities of the three poisons tested could be summed to give the toxicity of the mixture, the 95% confidence intervals effectively embracing the value of 1·0. With zinc predominating (> 70%) in the mixture, however, some antagonistic effect appears to be demonstrated.

645. Brule, G., M. Falempin, and P. Guilbault. 1972. Les ions potassium (K^+), calcium (Ca^{++}) et sodium (Na^+) dans le developpement de la contracture potassique de la fibre striee phasique de crabe. Sciences Naturelles 275(15):1649-1652.

The action of the ions K^+, Ca^{++}, and Na^+ on contraction of striated muscular fibers of the crab Carcinus maenas was studied. The role of the extracellular concentration of Na^+ and K^+ on the entry of Ca^{++} was demonstrated, as was the existence of 2 antagonisms: Ca^{++}-Na^+, and Ca^{++}-K^+.

646. Brungs, W.A., E.N. Leonard, and J.M. McKim. 1973. Acute and long-term accumulation of copper by the brown bullhead, Ictalurus nebulosus. Jour. Fish. Res. Bd. Canada 30(4):583-586.

Bullheads were exposed to constant concentrations of copper ranging from 6.5 to 422 μg/liter. Copper concentrations in gill, opercle, liver, and kidney tissues of live fish did not differ from those that died during the acute exposure. Exposure of fish to sublethal concentrations for 20 days before exposure to lethal concentrations resulted in higher tissue levels in the dead fish than in fish not previously exposed. A distinct increase in liver and gill tissue copper concentrations occurred at exposure levels of 27 μg/liter and above. Equilibrium tissue levels of copper in the liver and gill were reached within 30 days. Copper levels in red blood cells and plasma after 20-months exposure did not differ from the controls. Red blood cells analyzed after 6-days and 30-days exposure to copper also showed no increased copper residues.

647. Bryan, G.W. 1968. Concentrations of zinc and copper in the tissues of decapod crustaceans. Jour. Mar. Biol. Assn. U.K. 48:303-321.

Concentrations of zinc and copper have been measured in 18 species of decapod crustaceans, ranging from freshwater to purely marine species. Although the intake of zinc and copper probably varies considerably, the majority of animals contain between 20 and 35 μg/g of both metals. This is probably because the concentrations in the body fluids and tissues are regulated. Reasons for differences between the concentrations of zinc and copper in the individual tissues of different species are discussed and the ways in which regulation is achieved are compared.

648. Bryan, G.W. 1971. The effects of heavy metals (other than mercury) on marine and estuarine organisms. Proc. Roy. Soc. London B. 177:389-410.

Heavy metals including copper, zinc and lead are normal constituents of marine and estuarine environments. When additional quantities of metals are introduced from industrial wastes or sewage they enter the biogeochemical cycle and, as a result of being potentially toxic, may interfere with the ecology of a particular environment. In different marine organisms, including crustaceans, algae, annelids, bryazoans and fish, the behavior of Cu, Zn, Pb, Cd, Ni, Co, Ag, Cr, Sr, Fe, Ca and Mg is described in terms of their absorption, storage, excretion and regulation when different concentrations are available in the environment. At higher concentrations, the detrimental effects of heavy metals become apparent and their different toxic effects and factors affecting them are also described. A bibliography of 77 references is appended.

649. Bryan, G.W. 1973. The occurrence and seasonal variation of trace metals in the scallops Pecten maximus (L.) and Chlamys opercularis (L.). Jour. Mar. Biol. Assn. U.K. 53:145-166.

Concentrations of 11 trace metals in the tissues of two species of scallops collected from the same area of the English Channel were determined. Although there was considerable variation between individual animals, mean concentrations of Ag, Co, Cr, Cu, Mn, Ni, Pb, and Zn were higher in whole body of Chlamys than in Pecten but concentrations of Al, Cd, and Fe were lower. In both species, seasonal changes in concentrations of Co, Cu, Fe, Mn, Ni, Pb, and Zn were observed and, in general, the highest values were found in autumn and winter months. These changes may be related to food supply, since concentrations were generally highest when phytoplankton productivity was low and tended to fall in the spring as productivity increased rapidly to its annual peak. Despite problems arising from individual and seasonal variation, kidneys and digestive gland of scallops appear to have potential as biological indicators of trace metals. Results obtained for Pecten and Chlamys are compared with those in the literature for species from the family Pectinidae.

650. Bryan, G.W., and L.G. Hummerstone. 1971. Adaptation of the polychaete Nereis diversicolor to estuarine sediments containing high concentrations of heavy metals. I. General observations and adaptation to copper. Jour. Mar. Biol. Assn. U.K. 51: 845-863.

The concentration of copper in Nereis diversicolor is roughly related to the total concentration in the sediment, with particularly high levels in Nereis from areas where mining pollution occurs. In contrast, zinc concentrations in Nereis remain remarkably constant despite wide variations in the environment and appear to be accurately regulated. In worms from different estuaries, concentrations of copper have been related to those of the sediments. Sediment extracts and interstitial water at different stations, and the influence of salinity and size of animal has also been considered. The relative importance of copper absorption via gut or across the body surface is still uncertain, but uptake over the body surface appears to be important in high-copper animals from polluted areas; most of the Cu is deposited in epidermis of body wall and in nephridia. High-copper animals survive in polluted areas because they have developed a tolerance to the toxic effects of copper which is neither readily lost, nor readily gained by non-tolerant animals. The situation may be similar to that found on old mine dumps where populations of metal tolerant land plants have evolved.

651. Bryan, G.W., and L.G. Hummerstone. 1973. Brown seaweed as an indicator of heavy metals in estuaries in south-west England. Jour. Mar. Biol. Assn. U.K. 53:705-720.

Concentrations of copper, zinc, lead, manganese, and iron in the brown seaweed, Fucus vesiculosus have been measured in samples collected over its range of distribution in four estuaries having different degrees of metal contamination. Factors controlling the concentrations in the weed have been studied and include the concentrations of metals in the water, seasonal changes, the position of the weed in the intertidal zone and the particular portion of the plant which is analyzed. It is concluded that analysis of the weed gives a reasonable indication of average conditions in the water at points along an estuary and provides a method of making comparisons with the same estuary in subsequent years or with other estuaries.

652. Bryan, G.W., and L.G. Hummerstone. 1973. Adaptation of the polychaete Nereis diversicolor to manganese in estuarine sediments. Jour. Mar. Biol. Assn. U.K. 53:859-872.

Concentrations of manganese have been measured in Nereis diversicolor, interstitial water and sediments from estuaries draining the mineralized areas of South-West England. Results from the field observations have been supported by experiments using Mn-54. Manganese appears to occur in Nereis in two pools, one exchanging slowly and the other more rapidly. The slowly exchanging pool amounts to roughly 10 μg/g on a dry-weight basis and upon this is superimposed the more rapidly exchanging pool, the magnitude of which depends on several factors. The two most important of these are the concentration of manganese in the interstitial water and salinity. With decreasing salinity the concentration factor for manganese increases, and therefore the highest concentrations of manganese are usually found in animals from the least saline areas of an estuary.

653. Bryan, G.W., and L.G. Hummerstone. 1973. Adaptation of the polychaete Nereis diversicolor to estuarine sediments containing high concentrations of zinc and cadmium. Jour. Mar. Biol. Assn. U.K. 53:839-857.

Concentrations of zinc and cadmium in Nereis have been compared with those of sediments in estuaries of 26 rivers which drain the old metalliferous mining areas of South-West England. Whereas in the sediments concentrations of zinc varied by a factor of 30 from about 100 to 3000 μg/g, concentrations in the worms, after correcting for size, varied by only 2·7 from 130 to 350 μg/g dry weight. Concentrations of cadmium in the sediments varied by a factor of 46 from about 0·2 to 9·3 μg/g and concentrations in worms were roughly proportional to them and varied by a factor of 45 from 0·08 to 3·6 μg/g. These results suggest that zinc is regulated by the worm whereas cadmium is not.

Experimental work has shown that with increasing concentrations in solution the rate of absorption of cadmium by Nereis increases more rapidly than that of zinc and is more nearly proportional to the external concentration. This helps to explain why, in the field, concentrations of zinc in the worms vary less than those of cadmium, but another reason is that populations from high-zinc sediments are better at regulating zinc than normal populations. In toxicity experiments they are more resistant to zinc than normal worms and this adaptation is explained by a reduced permeability to zinc and probably to more effective excretion. Factors which influence absorption of heavy metals are discussed and adaptation of Nereis to high concentrations of metals is compared with that in other organisms.

654. Burrows, W.D., and P.A. Krenkel. 1973. Studies on uptake and loss of methylmercury-203 by bluegills (Lepomis macrochirus Raf.). Environ. Sci. Technol. 7(13):1127-1130.

The uptake of methylmercury-203 directly from water by bluegill sunfish was found to be nearly constant after five days at about 20% per gram of fish per liter of water. Transferred to mercury-free water at 24°C, bluegills exhibited a rapid loss of about 40% of the mercury, followed by a slow loss with a half-time of about five months. Mercury levels in the liver and kidneys were two to seven times higher than whole fish levels, but there was no discernible trend in this ratio with time. The proportion of mercury present as methylmercury in the whole fish remained at 73±10% throughout the course of the experiment. The proportion of methylmercury in the liver and kidneys, however, fell rapidly in the first few weeks after exposure, ultimately leveling off at about 10%. This suggests that biochemical demethylation is taking place in these organs.

655. Burton, D.T., E.L. Morgan, and J. Cairns, Jr. 1972. Mortality curves of bluegills (*Lepomis macrochirus*, Rafinesque) simultaneously exposed to temperature and zinc stress. Trans. Amer. Fish. Soc. 101(3):435-441.

Bluegills were exposed to a temperature-zinc interaction consisting of five temperature regimes and four concentrations of zinc which were 1.0, 5.6, 10.0 and 32.0 mg Zn^{++}/l. All of the above concentrations of zinc and a control were tested on five groups of fish which had been acclimated to (1) 20±1°C, (2) 30±1°C and fish which had been acclimated to 20±1°C and were exposed to temperature increases at the following rates: (3) 1°C/24 hours, (4) 1°C/1 hour, and (5) 1.5°C/10 minutes until a maximum of 30°C was reached.

This study showed that a rise in temperature could reduce the survival time of bluegills exposed to lethal and sublethal concentrations of zinc. Reductions in survival time were a function of the rates at which the temperature was increased. For example, bluegills acclimated to 20° and 30°C then exposed to a lethal concentration of zinc (32 mg Zn^{++}/l) at each temperature died 2.6 times faster at 30°C than at 20°C. Fish acclimated to 20°C and exposed to a temperature increase of 1.5°C/10 minutes died 4.8 times faster than fish maintained at 20°C. A sublethal zinc concentration (5.6 mg Zn^{++}/l) produced no mortalities in 20°C acclimated bluegills in 96 hours but was toxic to fish when the temperature was increased from 20° to 30°C at a rate of 1.5°C/10 minutes.

656. Burton, D.T., A.H. Jones, and J. Cairns, Jr. 1972. Acute zinc toxicity to rainbow trout (*Salmo gairdneri*): confirmation of the hypothesis that death is related to tissue hypoxia. Jour. Fish. Res. Bd. Canada 29:1463-1466.

Acute heavy metal toxicity to fish has been attributed to the coagulation or precipitation of mucus on the gills and/or to cytological damage to the gills. The physiological mechanism of death by either of the above causes is related to a breakdown in gas exchange at the gills. This study of acute zinc toxicity to rainbow trout (*Salmo gairdneri*) supports an earlier hypothesis that modification of the gas exchange process at the gills creates hypoxia at the tissue level. Tissue hypoxia appears to be a major physiological change preceding death once the gas exchange process at the gills is no longer sufficient to supply the oxygen requirements of the fish.

657. Button, D.K., and S.S. Dunker. 1971. Biological effects of copper and arsenic pollution. Final Report to U.S. Environ. Prot. Agen., Contract 18050 DLW, Rept. R71-8: Univ. Alaska, College, Alaska: 1-59.

Inhibitory effects of copper toward marine bacteria and yeasts were studied. Phosphate was found to prevent copper inhibition. These phosphate limited systems were found to be copper sensitive only under conditions of manganese deficiency. The protective influence in reagent grade phosphate was traced to contamination with trace amounts of manganese. Death occurred at about 10^{-6} M of Cu.

Among a number of metabolic inhibitors found to inhibit phosphate transport was arsenate. Phosphate also competitively reduced arsenate uptake. Reduced phosphate uptake rates occurred at 10^{-6} M arsenate and high death rates in cultures otherwise sustaining normal growth rates were induced with 10^{-7} to 10^{-8} M arsenate in phosphate deficient systems. These levels are exceeded in environmental and potable water systems.

Evidence is presented consistent with the view that both arsenate and phosphate are accumulated by the same active transport system. The system is peculiar in that velocities increase as the hydrogen ion is increased, saturation of the system does not occur, and the transport temperature coefficient is very large.

Evidence suggests that both arsenate and copper are important at existing concentrations in the environment. When nutrients are dilute these antimetabolites prevent microbial metabolism thus affecting the steady state chemistry which they control.

658. Byrne, J.M., F.W.H. Beamish, and R.L. Saunders. 1972. Influence of salinity, temperature, and exercise on plasma osmolality and ionic concentration in Atlantic salmon (*Salmo salar*). Jour. Fish. Res. Bd. Canada 29(8):1217-1220.

In unexercised Atlantic salmon (*Salmo salar*), plasma osmolality and Na^+ and Ca^{++} concentrations varied little at temperature-salinity combinations of 3, 5, 10, and 14°C and 0, 15, and 30‰. Plasma K^+ tended to increase with increase in temperature. Cl^- values were similar at 5 and 14°C. At 1°C and 0‰, lower plasma osmolalities indicated reduced ability to osmoregulate. At 1°C and 30‰, elevated osmolalities and ionic values and mortalities indicated severe osmotic stress. After exercise for 2 hr at 3-4 body lengths/sec at 5 and 14°C, salmon in salinities of 9 and 15‰ had osmolalities and ionic values the same as or little changed from unexercised values. There were marked increases in the values following exercise in 30‰.

659. Cain, T.D. 1973. The combined effects of temperature and salinity on embryos and larvae of the clam *Rangia cuneata*. Marine Biology 21:1-6.

Adult clams were spawned in the laboratory, and combined effects of temperature and salinity on survival of fertilized eggs and on survival and growth of larvae studied. Embryos and larvae were reared at temperature-salinity conditions within the ranges 8° to 32°C and 0 to 20^o/oo. Salinities near 0^o/oo were lethal in all cases. Optimum conditions for embryos (85% survival) were 18° to 29°C and 6 to 10^o/oo S. Salinity had more effect than temperature on early development. Optimum conditions for the larvae were broader, being 8° to 32°C and 2 to 20^o/oo S. Temperature and salinity interacted to reduce survival at low salinity-high temperature, and high salinity-low temperature combinations. Growth of larvae was best at high salinities and high temperatures.

660. Cairns, J., Jr., T.K. Bahns, D.T. Burton, K.L. Dickson, R.E. Sparks, and W.T. Waller. 1972. The effects of pH, solubility and temperature upon the toxicity of zinc to the bluegill sunfish (Lepomis macrochirus Raf.). Trans. Kans. Acad. Sci. 74(1):81-92.

Bluegills were exposed for 96 hr under static test conditions to water soluble $ZnSO_4 \cdot 7H_2O$ and water insoluble $Zn_3(PO_4)_2 \cdot 4H_2O$ at two temperature ranges (21-24°C; 7-9°C) and two pH ranges (5.7-7.0; 7.3-8.8). Control fish were maintained in zinc-free water. No bluegills died in water containing insoluble zinc in amounts comparable to the amounts of soluble zinc (13, 18, 24, and 32 mg Zn^{++}/l) which produced mortalities of 90 to 100%. Bluegill mortalities in concentrations of soluble zinc ranging from 10 to 32 mg Zn^{++}/l were 0 to 10% at the high pH, while at the low pH mortalities were 100%. Bluegills at the low temperatures died at a much slower rate, and the time-to-death of the first fish was considerably delayed, in comparison to bluegills at the warmer temperature. Continuous flow bioassay tests in which two types of test containers were used showed differences in LC-50 (96 hr) values. The particle replacement time in 19-liter bioassay jars was considerably longer than in 1.4 liter plexiglass containers, hence bluegills survived longer in the jars. LC-50 (96 hr) concentrations for fish exposed to a continuous flow of Zn^{++} in two types of test containers were estimated in four ways: using statistically pooled measured and calculated concentrations, and by pooling calculated and measured concentrations on the basis of the nominal concentrations alone. There were negligible differences in the resulting LC-50 values.

661. Cairns, J., Jr., N.H. Cromer, T.K. Bahns, and W.T. Waller. 1971. A confirmation of Mount's autopsy technique for zinc-caused fish mortality. Water Resources Bulletin, Jour. Amer. Water Res. Assoc. 7(5):956-968.

A total of 203 bluegill sunfish (Lepomis macrochirus) which had been used in several acute zinc experiments carried out under varied environmental conditions were autopsied according to Mount's procedure for determining fish mortality due to zinc poisoning. Three classes of fish were used: those exposed to but not killed by zinc; those killed by zinc; and those not exposed to zinc. Two statistical tests were used to analyze these data and both tests gave results indicating significant differences between all three classes of fish. This indicates that the Mount autopsy technique is very probably a valid generalization. The possibilities of using Mount's technique as a predictive tool are discussed.

662. Cairns, J., Jr., and K.L. Dickson. 1970. Reduction and restoration of the number of fresh-water protozoan species following acute exposure to copper and zinc. Trans. Kans. Acad. Sci. 73(1):1-10.

Protozoan communities established in plastic troughs through which Douglas Lake (Michigan) water was pumped were exposed for 24 hr to either 24 mg/l of Zn^{++} or 24 mg/l of Cu^{++}. The reduction in the number of species and density changes are described and the residual effects and recovery are discussed.

663. Cairns, J., Jr., and J.J. Loos. 1967. Changed feeding rate of Brachydanio rerio (Hamilton-Buchanan) resulting from exposure to sublethal concentrations of zinc, potassium dichromate, and alkyl benzene sulfonate detergent. Proc. Pennsyl. Acad. Sci. 40:47-52.

Zebra danios were exposed to 3.7 and 6.7 mg/l Zn^{2+}, 56 and 75 mg/l $K_2Cr_2O_7$, and 10 and 32 mg/l ABS mixture (54.8% active ingredient) under controlled conditions. The time required for each fish to consume ten out of twenty pieces of tubifex worms was determined at 0, 24, 48, 72, and 96 hours. Although the response of individuals varied markedly, after 96 hours of exposure the majority of exposed fish required more time to consume the allotted food than did the majority of the control fish.

664. Cairns, J., Jr., E.L. Morgan, and R.E. Sparks. 1972. Application of biological monitoring systems to simulated industrial waste discharge situation. Available from Nat. Tech. Inf. Ser., Springfield, Va., as PB-213 468:1-25.

Temperature, calcium concentration, pH and dissolved oxygen concentration have been shown to modify the toxicity of zinc, copper, and other heavy metals to fish. Since these factors interact, and because stream and industrial waste characteristics vary, it becomes difficult to rapidly predict the toxicity of zinc and other materials to aquatic organisms at an industrial or municipal facility from physical and chemical data alone; therefore, techniques were developed for measuring breathing rates and movement activities of fish. Responses were analyzed to determine if stress responses occur to complex environmental changes. Calcium at 147 mg/l did not cause continued stress detections. Bluegills did not become incapable of responding to a simulated zinc spill (3 mg/l) after long term exposure (41 weeks) to what is presumed a biologically safe concentration (0.075 mg/l). Calcium (110 mg/l) acts antagonistically with zinc (3.7 mg/l), but copper (0.3 mg/l) does not appear to act synergistically with 1.4 mg/l zinc. A daily change in temperature of 5°C produced a number of detections when no toxicant was present. However, when the first temperature treatment day is used to establish baseline breathing rates then no detections are obtained on the following treatment days. These biological monitoring techniques should be applicable in field situations for detecting not only heavy metals, but other toxicants as well.

665. Cairns, J., Jr., and A. Scheier. 1968. A comparison of the toxicity of some common industrial waste components tested individually and combined. Progr. Fish-Culturist 30(1):3-8.

Toxicities of salts of Zn^{2+}, Cu^{2+}, and Cr^{6+} alone and in combination with acetaldehyde, acetic acid, acetone, cyanide, and napthenic acids, were determined for bluegill sunfish over a period of 96 hours. Concentrations fatal to 0, 50, and 100% in 96 hours = LC-0, LC-50, LC-100 values were computed. For Zn^{2+}, these values were 2.4, 4.2, and 5.9 mg/l, respectively. For Cu^{2+}, LC-0, LC-50, and LC-100 values were 0.75, 1.25, and 2.10 mg/l. For Cr^{6+}, values were 48.4, 113.0, and 176.8 mg/l, respectively. Toxicity bioassays with Zn^{2+} + CN^- mixtures suggested a slight antagonistic interaction between these two ions, probably because the zinc complexed with the cyanide and thereby slightly reduced the toxicity of the cyanide. Mixtures of acetic acid, acetaldehyde, and Cu^{2+} suggest no substantial interaction between the components in toxicity assays.

666. Cairns, J., Jr., and R.E. Sparks. 1971. The use of bluegills to detect zinc. U.S. Environ. Protect. Agen. Rep. 18050 EDQ:1-45.

The presence of zinc at concentrations of 8.7, 5.22, 4.16, and 2.55 mg/l in dechlorinated municipal tapwater was detected by an increase in breathing rate or a change in breathing rate variance of bluegills. None of the fish exposed to the three lower concentrations died during the experiments. The criterion for detection was an arbitrary number of responses occurring at the same time. When the criterion was changed from a single response to three responses occurring at the same time, the number of false detections ("detections" occurring before zinc addition) decreased, but the lag between zinc addition and detection increased.

Zinc concentrations of .025 and .075 mg/l (approximately 1/100 and 1/34 of 2.55 mg/l, respectively) did not appear to affect the reproduction and growth of bluegills in the laboratory, but .250 mg/l zinc (approximately 1/10 of 2.55 mg/l) inhibited spawning in ripe bluegills and killed newly-hatched fry.

667. Cairns, J., Jr., R.E. Sparks, and W.T. Waller. 1973. The use of fish as sensors in industrial waste lines to prevent fish kills. Hydrobiologia 41(2):151-167.

The use of movements and breathing rates of bluegill sunfish as in the detection of sublethal concentrations of zinc can be applied to industrial waste lines.

668. Cairns, J., Jr., and W.T. Waller. 1971. The use of fish movement patterns to monitor zinc. U.S. Environ. Protect. Agen. Rep. 18050 EDP:1-55.

The feasibility of using fish movement patterns measured by light beam interruption as a technique for continuous monitoring of the response of fish to zinc was investigated. In conjunction with the monitoring studies growth and reproductive success of bluegill sunfish (Lepomis macrochirus) exposed to various fractions of the lowest concentration of zinc detected were studied.

The monitoring apparatus does not interfere with fish movement within the test chamber and allows for maintenance of fish for long time periods. Under the conditions described the system detects aberrations in fish movement caused by zinc in sufficient time to permit survival of test fish if stress conditions are reversed at time of detection. The lowest concentration of zinc detected by the system during a 96-hour exposure was between 3.64 and 2.94 mg/l Zn^{++}.

Growth and reproductive success of bluegill was tested in concentrations approximately equal to 1/10 and 1/100 the lowest concentration of zinc detected by the monitoring system and 1/100 of the LC-50 (96 hr) determined under continuous flow conditions. The growth and reproductive success in 1/100 the lowest detected zinc concentration and 1/100 the 96 hour LC-50 value did not differ appreciably from controls while a concentration of approximately 1/10 the lowest detected zinc concentration in effect eliminated reproduction in the bluegill.

669. Cairns, J., Jr., W.T. Waller, and J.C. Smrchek. 1969. Fish bioassays contrasting constant and fluctuating input of toxicants. Revista Brasileria e Portuquesa de Biologia em Geral 7(1-2):75-91.

Bioassays of 96 hour duration were conducted with fish exposed to LC-50 (96 hr) concentrations of zinc and 2 medium replacement rates. In one study half the test solution was replaced every 24 hours with test solution containing the same concentration of zinc. Results of this study indicate that Zn is more toxic under these conditions than tests in which the replacement solution had half this concentration of zinc every other time. However, the apparent difference in response was so slight that considerably more experimental work would be required to establish statistically significant differences.

670. Calabrese, A., R.S. Collier, D.A. Nelson, and J.R. MacInnes. 1973. The toxicity of heavy metals to embryos of the American oyster Crassostrea virginica. Marine Biology 18:162-166.

The acute toxicity of salts of 11 heavy metals to oyster embryos was studied and the concentrations at which 50% of the embryos failed to develop determined. The most toxic metals and their LC-50 (48 hr) values were mercury (0.0056 mg/l), silver (0.0058 mg/l), copper (0.103 mg/l), and zinc (0.31 mg/l). Those metals that were not as toxic and their LC-50 (48 hr) values were nickel (1.18 mg/l), lead (2.45 mg/l), and cadmium (3.80 mg/l). Those metals that were relatively non-toxic and their LC-50 (48 hr) values were arsenic (7.5 mg/l), chromium (10.3 mg/l), and manganese (16.0 mg/l). Aluminum was non-toxic at 7.5 mg/l, the highest concentration tested.

671. Calabrese, A., and D.A. Nelson. 1974. Inhibition of embryonic development of the hard clam, Mercenaria mercenaria, by heavy metals. Bull. Environ. Contamin. Toxicol. 11(1):92-97.

The present study was undertaken to determine the effect of salts of mercury, silver, zinc, nickel, and lead on the survival and subsequent development of embryos of the hard clam at 26°C and 25°/oo salinity, in synthetic seawater. LC-50 (48 hr) values, in mg/l element added at start, were 0.0048 for Hg, 0.021 for Ag, 0.166 for Zn, 0.31 for nickel, and 0.78 for lead.

672. Calamari, D., and R. Marchetti. 1973. The toxicity of mixtures of metals and surfactants to rainbow trout (Salmo gairdneri) (Rich.). Water Research 7:1453-1464.

The toxicity to rainbow trout of copper and mercury and two anionic and one non-ionic detergents were determined with an exposure period of 14 days. Each compound was tested separately and as a metal-detergent pair. The results show that for the mixtures of anionic detergents and metals a "more-than-additive" effect exists, while for the mixture of non-ionic detergent and metal the toxic effect is probably "less-than-additive." These findings are compared with existing data in the literature and the underlying reasons for these effects are discussed.

673. Campbell, I.R., and E.G. Mergard. 1972. Biological aspects of lead: An annotated bibliography--literature from 1950 through 1964. Parts I and II. U.S. Public Hlth. Serv. Doc. ES 00159, Rept. AP-104 May, 1972. Contract CPA 22-69-48:1-935.

This bibliography has been compiled from several abstract sources and represents the scientific periodical literature covered by the principal abstracting and indexing services. Books and proceedings of conferences and symposia devoted to lead and its compounds are also included. The material is arranged in 10 sections covering such areas as environmental surveys, plants and animals, man, occupational exposure, pollution and effects, legal aspects, analytical methods, and chemistry and technology.

674. Cancio, D., J.A. Llauro, N.R. Ciallella, and D.J. Beninson. 1973. Incorporacion de radioestroncio por organismos marinos. In Radioactive Contamination of the Marine Environment, Int. Atom. Ener. Agen., Vienna, Austria:347-357.

The paper reports on discrimination factors for strontium and calcium and the corresponding strontium concentration factors. It includes results of laboratory experiments using double tracer techniques and of determinations based on systematic measurements of stable strontium and calcium. The organisms studied are common along the Atlantic coastline of Argentina and include various species of fishes, crustaceans, molluscs and marine algae.

From the laboratory experiments it is possible to determine discrimination factors even before equilibrium conditions have been established. All organisms studied discriminate against strontium, the discrimination factor values fluctuating between 0.10 and 0.92 depending on the species. In fish, Micropogon opercularis, the Sr/Ca ratios were the same throughout the animal, as was also true with exoskeletons and soft parts of crustaceans. In molluscs, different values were obtained for shells and soft parts.

In general, discrimination factors obtained in the field on the basis of strontium and calcium determinations agree reasonably well with values obtained in the laboratory for fishes and molluscs, but are lower for crustaceans and algae. Obtaining concentration factors from discrimination parameters has the advantage of representing limiting situations where the equilibrium state is ensured. In this way, experimental results can be extrapolated to natural conditions with less uncertainty. The resulting strontium concentration factors fluctuate between 2 and 10 for fish, 13 and 70 for crustaceans and molluscs, and 0.2 and 70 for algae.

675. Carey, A.G., Jr. 1970. Zn65 in benthic invertebrates off the Oregon Coast. Available from Nat. Tech. Inf. Ser., Springfield, Va., as RLO-1750-55:1-27.

More Zn-65 was found in detritus feeders as compared with carnivores, and in surface as compared with sediment feeders. From the 50-200 m shelf zone to 1400 m deep, the specific activity of detritus feeders decreased from 54 to 6 nanoCi/gram stable Zn. From 100 to 800 m, the activity of asteroids decreased from 32 to 4 picoCi/gram ash. The average Zn-65 in surface water may increase for a period during the night from the upward migration of nektonic animals. According to wind and current, pelagic animals may be higher in Zn-65 off central Oregon as compared with those in closer proximity to the mouth of the Columbia River.

676. Carey, A.G., Jr., and N.H. Cutshall. 1973. Zinc-65 specific activities from Oregon and Washington continental shelf sediments and benthic invertebrate fauna. In Radioactive Contamination of the Marine Environment, Int. Atom. Ener. Agen., Vienna, Austria:287-305.

Relationships between benthic fauna and sediments on the continental shelf of Oregon and Washington have been investigated by determining specific activities of Zn-65. Zinc-65, induced by neutron activation in Columbia River water used to cool plutonium production reactors at Richland, Washington, was carried down the river and into the marine environment. Sediment from the Columbia River moves northward. Zinc-65 specific activities in sediment and benthic invertebrates decrease northward with distance from the river and westward with both distance and depth. Many organisms to the south of the river mouth and westward with depth have higher Zn-65 specific activities than the sediments in, or on, which they live. Other sources of Zn-65 via the food web are suspected as the cause for the difference in specific activity between the sediment and benthic fauna. Long-term declines in Zn-65 specific activities have been noted. Many species from a range of trophic levels have been included in the study.

677. Carlson, C.A., and M.H. Shealy, Jr. 1972. Marking larval largemouth bass with radiostrontium. Jour. Fish. Res. Bd. Canada 29(4):455-458.

Largemouth bass (Micropterus salmoides) were marked by exposing newly-hatched prolarvae to 6.4, 11.3, and 16.8 $\mu Ci\,^{85}Sr$/liter pond water for 7 days. Embryos were collected by pipette from nests in ponds and incubated to hatching in disposable aquaria in the laboratory. Radiostrontium accumulation from water continued throughout the first week of postembryonic life but was most rapid after the fourth day of exposure. In another study the techniques were found useful for quantifying predation on larval bass by aquatic invertebrates.

678. Carpenter, K.E. 1927. The lethal action of soluble metallic salts on fishes. Jour. Exp. Biol. 4:378-390.

A study of pollution of Welsh rivers by lead-mine-effluents showed that fishes were killed by the action of soluble salts of lead, at concentrations as low as 0.3 mg/l Pb. Laboratory studies showed that the speed of the toxic reaction is dependent upon the total quantity of metallic ion present, as well as upon the actual concentrations and varies in inverse relation to the size and weight of fishes employed. The most marked symptom is formation of a film over gills and skin, by interaction of the metallic ion with a mucus-constituent. Death by suffocation is the final result. Where insufficient lead ion is present, the film is sloughed, and complete recovery takes place. The speed of the reaction varies in direct relation to the temperature. Chemical analysis of residues shows that no trace of metallic ion penetrates into the body itself. The action is thus held to be purely external in process, chemical in type, and mechanical in effect; i.e. it is not a "toxic" action in the ordinary sense of the term. The action of soluble salts of zinc, iron, copper, cadmium and mercury is shown to follow the same law as that of lead.

679. Carter, J.W., and I.L. Cameron. 1973. Toxicity bioassay of heavy metals in water using Tetrahymena pyriformis. Water Research 7:951-961.

The toxicities of 5 heavy metal compounds on survival of the ciliated protozoan *Tetrahymena pyriformis* were determined. Three-day old cultured cells were exposed to 5 concentrations of each test compound in one or more of three water series: distilled, soft, and hard water. A culture of each sample was placed in a petri dish and covered with mineral oil to prevent evaporation. The cells were counted initially, then again at 0.5, 1, and 2 hours, 1, 2, 3, and 4 days. On a weight basis cadmium was most toxic, followed in decreasing toxicity by mercury, cobalt, zinc, and lead. Compared to similar fish data, all heavy metals were more toxic to *T. pyriformis* except lead. The toxicity of lead in soft versus hard water exemplified an antagonistic effect with greater than seven times the amount of lead necessary in hard water to produce comparable mortality as lead in soft water. On the other hand, the toxicity of mercury is about twice as great in hard water as in soft water (a synergistic effect). *T. pyriformis* appears to be a more sensitive indicator than fish of heavy metal contamination of water. *T. pyriformis* bioassay should prove a good means of determining the existence of many water pollutants.

680. Castagna, M., and P. Chanley. 1973. Salinity tolerance of some marine bivalves from inshore and estuarine environments in Virginia waters on the western Mid-Atlantic Coast. Malacologia 12(1):47-96.

Many species of estuarine bivalves have a distribution pattern closely correlated with salinity, indicating the importance of salinity in determining these patterns. The approximate salinity tolerance range for 36 species of bivalves is described. Tolerance limits for 29 species were determined in laboratory experiments. Most of these species display a remarkable degree of euryhalinity. All survived a minimum salinity of at least 17.5°/oo and 25 species survived at 12.5°/oo. Twenty species survived at various lower salinities.

Salinity tolerance for a given species is not constant but varies with season, salinity experience, and temperature. Burrowing, feeding and reproduction usually occur at nearly all salinities at which survival is possible. Byssal formation requires a higher salinity than is necessary for other activities.

In Virginia about two-thirds of the species of salt-water bivalves discussed can be found over the entire salinity range they are capable of tolerating in the laboratory. Eleven species do not occur over their entire potential salinity range. Eight of the 11 species, *Yoldia limatula*, *Mytilus edulis*, *Venericardia tridentata*, *Lucina multilineata*, *Dosinia discus*, *Abra aequalis*, *Mya arenaria*, *Martesia cuneiformis*, are near the geographic limit of their range; their distribution locally may be limited primarily by the factors that determine their geographic range. The distribution of 5 species, *Argopecten* irradians, Congeria leucophaeta, Macoma mitchelli, Donax variabilis, and Spisula solidissima, may be influenced by predation, competition, or special environmental requirements. Four of the 11 species, Congeria leucophaeta, Macoma mitchelli, Donax variabilis, Rangia cuneata, occur in specialized habitats with low species diversity.

681. Cearley, J.E., and R.L. Coleman. 1973. Cadmium toxicity and accumulation in southern naiad. Bull. Environ. Contamin. Toxicol. 9(2):100-101.

The effects of three different levels of cadmium on uptake and accumulation of this metal by the southern naiad, a waterweed, were investigated. A static bioassay was conducted over a 21-day period using duplicate exposure chambers for each exposure level. The plants were acclimated for 2 weeks and the roots removed before placement in the containers. Plants were exposed to different Cd levels for zero, 11 and 21 days. After exposure, the plant tissues were rinsed, dried for 24 hr at 100°C, ashed for 24 hr, and analyzed by spectrophotometry. Exposed plants showed reductions of chlorophyll, turgor, and stolon development not seen in controls. Toxic reactions and Cd accumulation by the plants increased as the exposure levels increased, which suggested that (a) Cd accumulation of about 1000-fold was a direct function of the exposure level, and (b) the detoxifying mechanism was over-taxed at a more rapid rate at higher levels resulting in an earlier impairment of physiological function. It is evident that this common aquatic plant is capable of introducing potentially toxic quantities of cadmium into the food chain of higher organisms.

682. Chapman, G. 1973. Effect of heavy metals on fish. In Heavy Metals in the Environment; Proc. Seminar at Oregon State Univ., Corvallis, Oregon, 1972: Avail. from Oregon State Univ. Water Resources Res. Inst. Rep. SEMN WR 016.73:141-162.

A review of literature with respect to the toxicity to freshwater fish of zinc, copper, and cadmium, showed a wide range of LC-50 (96 hr) values. For zinc this range was 90 to 40,900 μg/l; for copper 46 to 10,000 μg/l, and for cadmium 470 to 9,000 μg/l. Two general conclusions are that toxicity varies inversely with hardness, and that salmonids (trout and salmon) are more susceptible than most other common freshwater teleosts. Disregarding species and age, all other generally recognized factors which influence toxicity of heavy metals to fish do so by influencing rate of accumulation of metal and, primarily, rate of uptake. Thus pH, hardness and alkalinity, temperature, and dissolved oxygen content influence rate of uptake of the metal by changing either the biological availability of the metal by altering its form or by altering the rate and volume of ventilation of the fish.

683. Chau, Y.K., V.K. Chawla, H.F. Nicholson, and R.A. Vollenweider. 1970. Distribution of trace elements and chlorophyll-A in Lake Ontario. Inter. Assoc. Great Lakes Research, Proc. 13th Conf. on Great Lakes Research, Part 2:659-672.

Attempts were made to correlate the subsurface content of chlorophyll a with horizontal and vertical distribution of trace elements, Cd, Cr, Co, Cu, Fe, Pb, Mn, Mo, Ni, Sr, V, and Zn, in Lake Ontario. Sampling was performed during May, July, and September of 1969; subsequent analyses showed correlation between concentration of subsurface chlorophyll a and content of zinc alone and zinc in combination with copper and iron. In general, high values of chlorophyll a coincided with high concentration of trace elements, but no correlations were statistically significant. Bioassays with water from Lake Ontario suggested that an addition of manganese stimulates photosynthesis.

684. Chau, Y.K., and J.P. Riley. 1965. The determination of selenium in sea water, silicates and marine organisms. Anal. Chim. Acta 33:36-49.

Spectrophotometric procedures are described for the determination of selenium in sea water, silicates (especially marine sediments) and marine organisms. For sea water, which contains ca. 0.4-0.5 μg Se/l, a standard deviation of 0.03 μg/l was obtained. A silicate sediment and a seaweed contained ca. 1.5 μg Se/g and 0.8 μg Se/g respectively.

685. Chen, C.W., and R.I. Selleck. 1969. A kinetic model of fish toxicity threshold. Jour. Water Pollution Control Fed. 41: 294-308.

A procedure is presented to determine threshold concentrations of mixtures of toxicants and to evaluate proportional amounts of toxicity of individual components, taking into account synergistic and antagonistic effects. For experimental verification of the model, zinc and cyanide were selected as toxicants. The survival function describing the fish bioassay data was found to be exponential after an initial induction period. The exponential rate coefficient is a function of at least four other coefficients when toxicant concentration is constant. The threshold concentrations of zinc and cyanide under the specified experimental conditions are 0.33 and 0.236 mg/l, respectively.

686. Childs, E.A., and J.N. Gaffke. 1973. Mercury content in Oregon ground fish. U.S. Dept. Comm., Fish. Bull. 71(3):713-717.

The Hg content of rex sole, *Glyptocephalus zachirus*; Dover sole, *Microstomus pacificus*; petrale sole, *Eposetta jordani*; English sole, *Parophrys vetulus*; and sand sole, *Psettichthys melanosictus*; starry flounder, *Platichthys stellatus*; canary rockfish, *Sebastes pinniger*; flag rockfish, *S. rubrivinctus*; yellowtail rockfish, *S. flavidus*; rougheye rockfish, *S. aleutianus*; sablefish, *Anoplopoma fimbria*; lingcod, *Ophiodon enlongattus*; Pacific hake, *Merluccius productus*; and arrowtooth flounder, *Atheresthes stomias*, was significantly less than 0.50 mg/kg. However, all spiny dogfish, *Squalus acanthias*, samples contained more than 0.50 mg Hg/kg wet wt.

687. Childs, E.A., J.N. Gaffke, and D.L. Crawford. 1973. Exposure of dogfish shark feti to mercury. Bull. Environ. Contamin. Toxicol. 9(5):276-280.

Feti of the primitive anamniote *S. suckleyi* are not exposed to the high concentrations of mercury found in maternal musculature even though they have an equivalent content of other metals.

688. Chipman, W., and J. Thommeret. 1970. Manganese content and the occurrence of fallout 54Mn in some marine benthos of the Mediterranean. Bull. de l'Institut Oceanographique 69(1402): 1-15.

Marine benthos of the Mediterranean were investigated for Mn-54 accumulation. The ascidian *Halocynthia papillosa*, the lamellibranch mollusc, *Pinna nobilis*, and the annelid worm, *Hermione hystrix* all showed high Mn-54 content. Detectable amounts of Mn-54 were found in the ash of the tube worm, *Spirographis spallanzani*. In *Pinna* the highest concentrations were in hepatopancreas. In polychaete worms, concentrations were found in the external body structures. Although high radioactivity from Mn-54 fallout was usually related to high manganese content in the organism, the specific activity of Mn-54 varied. Among fallout radionuclides, Promethium-147 seemed to be present in those organisms that concentrate Mn-54.

689. Chittenden, M.E., Jr. 1971. Effects of handling and salinity on oxygen requirements of the striped bass, *Morone saxatilis*. Jour. Fish. Res. Bd. Canada 28(12):1823-1830.

Oxygen requirements of striped bass, *Morone saxatilis*, were studied at 0 and 10% salinity using combinations of handling and constantly decreasing oxygen concentrations. Effects of handling and salinity on oxygen requirements were negligible or absent.

690. Chittenden, M.E., Jr. 1972. Salinity tolerance of young blueback herring, Alosa aestivalis. Trans. Amer. Fish. Soc. 101 (1):123-125.

Experiments indicate that the blueback herring is highly salinity tolerant early in life. Euryhaline tolerance allows this species to occupy both saltwater and freshwater nurseries.

691. Chittenden, M.E., Jr. 1973. Salinity tolerance of young American shad, Alosa sapidissima. Chesapeake Science 14(3):207-210.

Shad were subjected to abrupt and gradual changes between saltwater and freshwater media. No mortality occurred with salinity increase, even abrupt change from freshwater or 5°/oo salinity to about 30°/oo salinity. Complete mortality occurred with abrupt salinity decrease from about 30 to 0°/oo but not with gradual decrease from about 5 to 0°/oo. Fish tolerate salinity change, especially salinity increase. Instances of apparent intolerance of salinity change may be primarily due to handling stress.

692. Christensen, G.M. 1971. Effects of metal cations and other chemicals upon the in vitro activity of two enzymes in the blood plasma of the white sucker, Catostomus commersoni (Lacépède). Chem.-Biol. Interactions 4(1971/72):351-361.

Relative changes in the activity of fish enzymes (glutamic oxalacetic transaminase, L-aspartate-2-oxoglutarate aminotransferase, and lactic dehydrogenase) was determined after incubation with 49 compounds, principally inorganic chlorides, at concentrations of the ions up to 2 mg/ml in the reaction mixture. A sequence of inhibitory effect was arranged for each enzyme. Dose-response curves were qualitatively similar for most of the chemicals. GOT was most sensitive to silver and mercury and LDH to palladium and mercury. Both enzymes are highly inhibited by metals which are highly toxic to aquatic animals. Correlations were studied between the inhibitory effect and certain physicochemical properties of chemicals, the best being found between the inhibition of GOT and the equilibrium constants of metal sulfides.

693. Christensen, G.M., J.M. McKim, W.A. Brungs, and E.P. Hunt. 1972. Changes in the blood of the brown bullhead Ictalurus nebulosus (Lesueur) following short and long term exposure to copper (II). Toxicol. Appl. Pharmacol. 23(3):417-426.

Blood from brown bullheads exposed to Cu (II) from 3.4 to

104 µg/l for 6, 30, and 600 days was analyzed to identify and evaluate changes in red blood cells, hematocrit, hemoglobin, plasma chloride, plasma total protein, plasma glucose, plasma glutamic oxaloacetic transaminase (PGOT, W-aspartate: 2-oxoglutarate aminotransferase) and plasma lactic dehydrogenase (PLDH, L-lactate: NAD oxidoreductase). After 6 days, glucose and hematocrit increased significantly above the controls; after 30 days, chloride and protein decreased, and hematocrit, hemoglobin and glucose increased; after 600 days, the transaminase decreased. The maximum concentration of Cu (II) having no detectable effect upon the brown bullhead was determined to be between 11 and 16 µg/l.

694. Chu, S.P. 1942. The influence of the mineral composition of the medium on the growth of planktonic algae. Part I. Methods and culture media. Jour. Ecol. 30(2):284-325.

The experiment was one in which 14 planktonic algae were maintained in culture media simulating the chemical compositions of natural fresh waters. Algae were found to respond with considerable difference to concentrations of calcium, magnesium, potassium, sodium, and silica. The calcium requirement was often lower in media with higher magnesium concentrations, while excessive potassium increases tolerances for higher concentrations of calcium and magnesium. Appreciable quantities of silica were found to be necessary only for the growth of diatoms; some algae, in fact, were inhibited by dissolved silica.

695. Clarke, G.L. 1947. Poisoning and recovery in barnacles and mussels. Biol. Bull. 92:73-91.

Direct tests were performed on the concentrations and exposures of a variety of metallic salts necessary to kill barnacles. The toxicities of mercury, cupric citrate, cupric tartrate, cupric salicylate, and cupric aminobenzoate were found to be slightly less than the toxicity of basic cupric carbonate. The toxicity of silver is about equal to that of basic cupric carbonate, but the toxicity of zinc is very much less. The rate of killing of barnacles by cupric citrate is proportional to the concentration of the toxicant over the range tested. An extremely high concentration of copper or of mercury salts was necessary to prevent the metamorphosis of cyprids attached to glass plates. The results show the difficulty of preventing the initial attachment of cyprids, or their metamorphosis, by the use of copper paints. Moderate concentrations of cupric citrate seriously retard the development of the newly metamorphosed barnacles and prevent the second step in attachment, namely, the formation of the cemented calcareous base. Exposure of the newly metamorphosed barnacles to very low concentrations of cupric citrate accelerated development beyond that of the normal animals. The soft tissues of adult barnacles normally contain a much higher concentration of copper than does sea water. When placed in solutions of cupric citrate, barnacles absorbed more than 100 times the normal copper content of the tissues. In no case were barnacles killed by the absorption of less than 0.19 mg of copper per gram of dry weight--more than 10 times the normal content. In some cases barnacles which had absorbed 0.5 mg to 1.09 mg/g from toxic solutions revived when replaced in fresh sea water. It was demonstrated that when replaced in fresh sea water, barnacles can eliminate from their tissues as much as two-thirds of the copper which has been absorbed from toxic solutions.

Mussels are more sensitive to poisoning by cupric citrate than barnacles. When exposed to copper solutions, mussels take up copper more rapidly than do barnacles, and when replaced in fresh sea water, they eliminate it from their tissues more rapidly and extensively. In many cases in which a considerable portion of the copper was eliminated, the mussels nevertheless succumbed subsequently.

696. Clasen, J., and H. Bernhardt. 1974. The use of algal assays for determining the effect of iron and phosphorus compounds on the growth of various algal species. Water Research 8:31-44.

Algal assays were performed with unialgal cultures of Oscillatoria rubescens, Asterionella formosa, Synedra acus, Haematococcus pluvialis and Scenedesmus quadricauda. The method used differs in some important respects from methods described in the literature and these differences are explained in detail.

The algal crop measured as µg/l chlorophyll a was used to determine productivity of water samples tested. The following were tested: untreated water; water treated in a pilot plant for elimination of phosphorus and turbid materials; water samples from the pre-reservoir effluent; and water samples taken near the dam.

Fertility decreased in the following order: untreated water > pre-reservoir effluent > water from the reservoir > water treated in the pilot plant. The productivity of water samples rich in turbid materials and algae, was higher in heat sterilized samples than those prepared by filtration. There is a clear correlation between productivity of unfiltered sterilized water samples and their iron and total phosphorus content.

Using algal assays it was proved that the large decrease in productivity resulting from treating the main reservoir inflow, is chiefly due to the removal of phosphorus compounds, but also to the removal of iron and other unknown substances. There are indications that the amount of iron required for growth, as compared to that of phosphorus, varies greatly depending on the individual algal species.

The significance of the algal assay and its results relating to measures for limiting eutrophication using phosphorus removal plants is discussed.

697. Coleman, R.L., and J.E. Cearley. 1974. Silver toxicity and accumulation in largemouth bass and bluegill. Bull. Environ. Contamin. Toxicol. 12(1):53-61.

Exposure of juvenile largemouth bass and bluegill to silver (0.3 to 70 ug/liter) resulted in accumulation of this metal. The quantity of metal accumulated increased as exposure concentration increased with a subsequent equilibrium developing between the water and tissue concentrations. Metal accumulations in the bass tissues were highest in the internal organs, followed by the gills and remainder of the body. The greatest increase was exhibited in the gills. Zinc concentrations in the bass body remainder and the bluegill total body appeared to vary in an approximately inverse relationship to the initial accumulation of silver within the tissues. The bass were more sensitive to silver than the bluegill. Abnormal behaviour patterns were observed in both species.

698. Colmano, G. 1973. Molybdenum toxicity: Abnormal cellular division of teratogenic appearance in Euglena gracilis. Bull. Environ. Contamin. Toxicol. 9(6):361-364.

Abnormal Euglena cells, observed by chance and described in the literature as freaks, have been considered the result of abnormal cellular division of unknown cause. However, it was demonstrated that molybdenum in the growth medium can alter cellular division and induce clustered, dividing cells with three to nine cells attached to each other at one end. Some appeared as the "rigid forms" described in early literature. Some showed attached ends, swimming with seemingly normally developed flagella, and some separated completely and swam away as individuals.

699. Connor, P.M. 1972. Acute toxicity of heavy metals to some marine larvae. Marine Pollution Bull. 3(12):190-192.

The toxicity of copper, mercury and zinc to the larvae of oysters, shrimp, crab and lobsters has been examined over periods of up to 64 hours. Mercury was more toxic than copper and zinc, which had similar levels of toxicity. Over the experimental period, the relationship between toxicity and concentration was linear. Larvae were from 14 to 1,000 times more susceptible than adults of the same species. The median lethal concentrations (LC-50) of each metal to the most sensitive species of larvae, tested over a 48 hour period, exceeded the concentrations found in natural sea water by a factor of 100. For longer test periods, the LC-50 would be considerably less and this factor would then be reduced.

700. Coombs, T.L. 1972. The distribution of zinc in the oyster *Ostrea edulis* and its relation to enzymic activity and to other metals. Marine Biology 12:170-178.

The role of zinc in oysters has been studied in its relation to the zinc-dependent enzymes present and in relation to the copper, calcium, magnesium, sodium, potassium and phosphate contents. Only carbonic anhydrase, alkaline phosphatase, carboxypeptidase A and malic dehydrogenase zinc metalloenzyme activities could be detected. α-D-mannosidase, a zinc-dependent enzyme hitherto not reported for the oyster, was also detected. After tissue dissection into muscle, palps, gills, mantle and digestive mass and subcellular fractionation of these tissues, analysis indicated that no single tissue concentrates zinc or the zinc-dependent enzymes. The total amount of zinc found is far in excess of the amount of zinc contributed by zinc-dependent enzymes, but amount of non-dialysable zinc is of the same order of magnitude. This apparent excess of dialysable zinc is a consequence of the high levels of calcium found in the tissues, demonstrating a competition between calcium and zinc in their uptake, as is well documented in many other phyla.

701. Cooper, M.F., and R.Y. Morita. 1972. Interaction of salinity and temperature on net protein synthesis and viability of *Vibrio marinus*. Limnology and Oceanography 17(4):556-565.

The relationship of temperature and salinity to protein synthesis was determined for cells of *Vibrio marinus*. The critical temperature of the lesion in protein synthesis increased with increasing salinity of the growth medium. Protein synthesis was significantly inhibited at 22°C at a salinity of 25^{o}/oo, but not at a salinity of 35^{o}/oo until the cells were incubated for 20 min at 24°C. The thermal lesion did not involve precursor accumulation mechanisms rather than protein synthesis at salinities between 25 and 35^{o}/oo. At 40^{o}/oo, the uptake of extracellular proline by whole cells was inhibited at 24°C and preceded the inhibition of precursor into protein.

Total RNA synthesis continued for 50 min at 22°C in growth media at salinities between 15 and 35^{o}/oo but at 40^{o}/oo decreased after 20 min of cell incubation. At salinities between 15 and 30^{o}/oo total RNA synthesis continued at 15 and 22°C, but cellular protein synthesis was inhibited by either temperature or salinity effects. Loss of cell viability at 22 and 25°C at salinities of 25 and 35^{o}/oo showed that onset of cell death occurs simultaneously with thermal inhibition of protein synthesis.

702. Copeland, R.A., and J.C. Ayers. 1972. Trace element distributions in water, sediment, phytoplankton, zooplankton and benthos of Lake Michigan: a baseline study with calculations of concentration factors and buildup of radioisotopes in the food web. ERG Special Report No. 1:1-271.

Samples of phytoplankton, zooplankton, benthos, water and sediment collected from Lake Michigan in 1969-70 prior to the operation of all nuclear plants except Big Rock Point, were analyzed for major and trace elements. Results indicate Lake Michigan is typical of other world environments in its chemical make-up although certain elements (selenium in zooplankton and chromium and zinc in water) show significant variation in distribution within the area surveyed. Biological investigation of the data indicate that conditions in the southern basin of Lake Michigan are rapidly changing. Major changes in the species make-up of phytoplankton are being discovered and further changes are expected in the near future. Calculations of concentration factors were made for the biota with respect to both water and sediment; concentration factors calculated with respect to water were most representative.

703. Corcoran, E.F., and J.F. Kimball, Jr. 1963. The uptake, accumulation and exchange of strontium-90 by open sea phytoplankton. In Schultz, V., and A.W. Klement, Jr. (eds.), Radioecology. Reinhold Publ. Corp., New York: 187-191.

Five cultures of oceanic phytoplankton were used to determine their ability to concentrate strontium from sea water. The experiments were short-termed and conducted during the active growth phases to eliminate the possibility of nutrient deficiencies and over-population, to minimize bacterial interference and to emulate natural conditions as closely as possible. Briefly, these results were as follows: 1) All cells grown in media containing Sr^{90}-Y^{90} became radioactive. Uptake of strontium was proportional to the concentration of strontium added. 2) Cells were able to concentrate radioactive strontium from 18 to 381 times the concentration in media. 3) Cell growth in media containing up to ten times the normal concentration of strontium was not inhibited.

4) High concentrations of strontium in media had little effect on ability of cells to accumulate strontium-90. 5) Absorption was found to play an important role in accumulation of strontium-90.

While these results are preliminary, it is noted that primary producers in the sea are capable of accumulating strontium-90 from sea water.

704. Corner, E.D.S. 1959. The poisoning of Maia squinado (Herbst) by certain compounds of mercury. Biochemical Pharmacology 2:121-132.

When Maia, a spider crab, is poisoned by immersion in sea water containing added $HgCl_2$, mercury concentrates at gills and other sites. Eventually the concentration of mercury in blood rises above that in external medium; the concentration in the antennary glands above that in blood; and animals excrete small but increasing amounts of poison in the urine. A high proportion (95%) of mercury present in blood is attached to protein, and concentration of mercury in blood remains fairly constant for several weeks after poisoned animals are returned to the sea. A similar pattern of mercury distribution is obtained when $HgCl_2$ is administered to the animals by injection, and there is evidence that animals so treated excrete small amounts of the poison through the gills. When poisoned with $n\text{-}C_5H_{11}HgCl$, mercury again concentrates at the gills and in various internal organs; but the amount detected in the blood is very small and none is found in the urine.

Amino acids present in the blood of normal Maia include alanine, a-aminobutyric acid, arginine, aspartic and glutamic acids, glutamine, glycine, isoleucine, leucine, lysine, proline, serine, taurine, threonine and valine. With the exception of taurine, all these amino acids are also present in the urine. In both these body fluids glycine, alanine, glutamic acid, proline and arginine preponderate; the other amino acids are present only in trace amounts. All fifteen amino acids, apparently in the same relative amounts, are also present in the blood of animals poisoned either with $HgCl_2$ or with $n\text{-}C_5H_{11}HgCl$; and, with the exception of taurine, in the urines of these animals. However, when the animals are immersed for progressively longer times in sea water containing $HgCl_2$, or are injected with increasing amounts of this poison, the total quantity of amino-N in the urine rises, although that in the blood does not significantly change. There is, therefore, an increase in the urine:blood ratio of amino-N. This ratio also increases when the animals are immersed in sea water containing $n\text{-}C_5H_{11}HgCl$, but in this case the level of amino-N in the blood rises as well as that in the urine. Animals poisoned with $HgCl_2$ and then returned to the sea still show an abnormally high urine:blood ratio of amino-N when examined several weeks later.

The levels of total sulphate in urine and blood of Maia used in this work were in the ratio 1·5:1. This ratio does not significantly change when the animals are poisoned with $HgCl_2$ under conditions that cause a marked increase in the excretion of amino-N.

The possible interference of mercury with mechanisms concerned with the metabolism of copper in Maia has been discussed, with especial reference to the influence of mercury on the functioning of the antennary glands.

705. Cory, R.L., W.O. Forster, W.C. Renfro, and J.W. Nauman. 1970. Radioactivity of three fresh-water molluscs of the tidal Columbia River and their associated sediments. In Hydrobiology, 'Bioresources of Shallow Water Environments.' Proc. Symp. held in Miami Beach, Fla., June 24-27, 1970; Amer. Water Res. Assoc., Urbana, Illinois, Proc. Ser. No. 8:162-173.

The levels of radioactivity in three species of freshwater bivalves (Anodonta and Corbicula spp), the levels of activity of the sediments in which they live, and relationships between sediment characteristics and the species distribution were determined. The principal source of the radionuclides is the Hanford reactors located approximately 500 km upriver from Astoria, Oregon. The Columbia River water, used to cool the reactors, is subjected to intense neutron flux which induces radioactivity in many trace elements in the water. Although there is a wide spectrum of radionuclides present, including those from fallout, zinc-65 and chromium-51 are most common. Results of this study indicate that Anodonta prefer sediment with a higher mud content than that preferred by Corbicula.

706. Cowell, B.C. 1965. The effects of sodium arsenite and silvex on the plankton populations in farm ponds. Trans. Amer. Fish. Soc. 94:371-377.

Neither sodium arsenite or silvex (weedicides) had any effect on the phytoplankton, and silvex was neither toxic nor inhibitory to zooplankton at concentrations of 2 mg/l. Applications of 4 mg/l sodium arsenite produced drastic reductions in zooplankton. Differences of between one and two orders of magnitude were observed when samples of rotifers from areas treated with sodium arsenite were compared with those from control of silvex-treated areas of the same pond. Similar comparisons of copepod-cladoceran samples showed differences which ranged from sevenfold to one order of magnitude. Such differences were not observed in any of the ponds where two control areas (untreated) were compared or where a control area and a silvex-treated area were compared.

707. Cross, F.A., T.W. Duke, and J.N. Willis. 1970. Biogeochemistry of trace elements in a coastal plain estuary: Distribution of manganese, iron, and zinc in sediments, water, and polychaetous worms. Chesapeake Science 11(4):221-234.

The distribution of Mn, Fe, and Zn in sediments, water, and in 6 species of polychaetes is described for the Newport River estuary near Beaufort, North Carolina. Concentrations of these elements in 0.1 N HCl extracts of sediment samples collected monthly from three stations for 2 years varied with element, location, time, and sediment type. At each station, iron was the most abundant element present in the 0.1 N HCl extracts and zinc was least abundant. The concentrations of all three elements in sediments decreased in a seaward direction. There were definite temporal fluctuations in concentration of these metals in sediment, although no seasonal trend was evident; muddy sediments were higher in trace metals than sandy sediments.

Levels of manganese and iron in water also decreased in a seaward direction, although concentrations of zinc remained relatively constant. Except for zinc at one station, at least 30% of the total amount of manganese, iron, and zinc in unfiltered water samples could not be measured by standard spectrophotometric techniques without prior treatment with acid. The relative order of enrichment of trace metals in sediment when compared with water was zinc > iron > manganese.

Concentrations of these elements varied in six species of polychaetous worms. Authors did not observe any intraspecific differences in concentrations of trace metals in 3 species of worms that were collected from two stations which had substantially different concentrations of trace metal in the sediment. This finding suggests that either these organisms may be able to regulate their trace metal content or that much of the metal associated with the sediment is in a chemical form which is unacceptable to them. The order of enrichment of trace metals in polychaetes relative to sediment and water was zinc > iron > manganese.

708. Cross, F.A., L.H. Hardy, N.Y. Jones, and R.T. Barber. 1973. Relation between total body weight and concentrations of manganese, iron, copper, zinc and mercury in white muscle of bluefish (_Pomatomus saltatrix_) and a bathyl-demersal fish (_Antimora rostrata_). Jour. Fish. Res. Bd. Canada 30:1287-1291.

Concentrations of mercury (Hg) increased significantly with size ($P < 0.001$) in white muscle of bluefish (Pomatomus saltatrix) and a bathyl-demersal fish Antimora rostrata but concentrations of manganese, iron, copper, and zinc either remained constant or decreased. These results indicate that fish residing in two different ecosystems in the Atlantic Ocean may be in a steady state with their environment with respect to Mn, Fe, Cu, and Zn but not Hg. The observed variations in accumulation patterns of trace metals in muscle of these two species as a function of size are discussed.

709. Cross, F.A., J.N. Willis, and J.P. Baptist. 1971. Distribution of radioactive and stable zinc in an experimental marine ecosystem. Jour. Fish. Res. Bd. Canada 28(11):1783-1788.

The distribution of radioactive and stable zinc in an experimental marine ecosystem is described. Authors added 1 mCi of Zn^{65} to 2000 liters of sea water and a mixed community of planktonic and benthic algae in a fiberglass tank, after which the ecosystem was left undisturbed for 9 months. Zn^{65} specific activities was determined for (1) particulate Zn (0.45 μ filterable), (2) extractable Zn (from water passed through a 0.45 -μ filter and then treated with dithizone), (3) total dissolved Zn (from samples passed through a 0.45 -μ filter and treated with acid prior to extraction with dithizone), and (4) dialyzable Zn. Zinc-65 specific activities were not significantly different among the extractable, dialyzable, or acid-treated samples of the water. Further, absolute concentrations of Zn^{65} and total Zn were no higher in the acid-treated samples than in extracted or dialyzed samples, which indicates that nearly all of soluble Zn in water was dithizone-extractable and dialyzable. Zinc-65 specific activities were significantly less however, in particulate material than in water. This difference indicates that equilibrium of Zn between particulate material and water had not been reached after 9 months. Three months later Zn^{65} specific activities were determined again for particulate material and total dissolved Zn. The mean specific activity of Zn^{65} in particulate samples showed a small but significant increase, but it was still less than in water. Concentration factors in particulate matter were 980 for Zn^{65} and 1400 for total Zn. Samples of benthic algae taken had a mean specific activity of Zn^{65} similar to the mean Zn^{65} specific activity of water samples taken 3 months earlier.

710. Cumming, K.B., and D.M. Hill. 1971. Stream faunal recovery after manganese strip mine reclamation. U.S. Environ. Protect. Agen. Report 18050 DOH:1-36.

Chemical, physical and biological monitoring and assessing stream faunal population differences evaluated manganese strip mine reclamation effects on faunal recovery. Toxicity studies, to determine whether silt and manganese levels were sufficiently high to limit fish survival, rule out the possibility that incident levels of manganese can be acutely toxic to the resident fish species. But turbidity and siltation levels associated with this operation adversely affect growth of trout, and species diversity of bottom taxa.

711. Cumont, G., G. Viallex, H. Lelievre, and P. Bobenrieth. 1972. Mercury contamination of fish of the sea. Rev. Internat. Oceanogr. Médicale 28:95-127.

Mercury determination in the muscle of various species of fish is researched. Results showed concentrations of this metal generally to be below the norms admissable for today's standards. The accumulation of mercury is always proportional to the weight of the fish. Consequently, the larger individuals at the end of the food chain are apt to have concentrations higher than these norms. Fish from certain areas showed abnormally high levels indicating a higher rate of mercury pollution in those specific areas.

712. Cunningham, P.A., and M.R. Tripp. 1973. Accumulation and depuration of mercury in the American oyster _Crassostrea virginica_. Marine Biology 20:14-19.

Adult oysters were held in seawater containing 10 μg mercury/l or 100 μg mercury/l, added in the form of mercuric acetate, for 60 days. Mercury concentration in tissues was determined by analysis of individually homogenized oyster meats, using wet digestion and flameless absorption spectrophotometry. After 45 days, average mercury tissue concentration was 140,000 μg mercury/kg tissue and 28,000 μg mercury/kg tissue in the 100 μg/l and 10 μg/l experimental groups, respectively. After this time, concentrations dropped sharply, probably due to spawning. Clearance of mercury from tissue was studied by exposing treated adults to estuarine water (with no additions) for 30 days (100 μg/l group) and 160 days (10 μg/l group). Tissue concentrations in the 100 μg/l mercury environment group declined from 115,000 to 65,000 μg/l, and those of the 10 μg/l group declined from 18,000 to 15,000 μg/l in 18 days; thereafter, no further decline occurred in either group. Oysters accumulated 1,400 times and 2,800 times above the environmental concentrations of 100 and 10 μg/l mercury, respectively. Total self-purification was not achieved over a 6 month cleansing period.

713. Cushing, C.E., and D.G. Watson. 1973. Cycling of zinc-65 in a simple food web. Proc. 3rd Nat. Symp. Radioecology, U.S.

Atom. Ener. Comm. Rept. BNWL-SA-3877, Conf. 71050-6: 318-322.

Passage of zinc-65 was followed through the periphyton-carp chain in four artificial streams spiked to 1 pCi/ml (two streams) or 10 pCi/ml (two streams). Light and current were uniform and water temperature, followed that of the Columbia River (about 6 to 18°C from January to June, the period of the experiments). Fish and periphyton in the river served as controls. Equilibrium uptake of zinc-65 was reached in about 28 days in periphyton (17 and 90 nCi/g), and in 43 days in the fish (0.25 and 1.3 nCi/g), although with the fish the increase in metabolic activity with increasing water temperature was a complicating effect. Data is also given in terms of specific activities (35 and 210 pCi/mg total zinc for periphyton, 3 and 15 pCi/mg total zinc for carp).

714. Cuthbert, A.W., and J. Maetz. 1972. Amiloride and sodium fluxes across fish gills in fresh water and in sea water. Compar. Biochem. Physiology 43(IA):227-232.

In the goldfish Carassius auratus, addition of amiloride to the external medium was without effect on the Na exchange fluxes across the gill. In the seawater-adapted eel Anguilla anguilla, amiloride, either injected or added to the external medium, was without effect on Na influx but increased the Na leak efflux component 2 to 3-fold. Injection of amiloride also produced a 70% increase of total Na efflux and a 100% increase of the Na/K exchange component, indicating augmentation of the Na extrusion pump efficiency. This latter effect may be secondary to an increased salt load, but the origin of this salt load remains obscure.

715. Dall, W. 1970. Osmoregulation in the lobster Homarus americanus. Jour. Fish. Res. Bd. Canada 27(6):1123-1130.

Lobsters took 72 hr to adapt to a salinity of 20^o/oo, with urine becoming markedly hypoosmotic to the blood during the first 24 hr, then increasing in concentration over the next 48 hr, though remaining significantly hypoosmotic to the blood. Adaptation to a salinity of 37^o/oo took 24 hr: the urine became almost isosmotic to the blood; the gastric and rectal fluids became hyperosmotic to the blood. Blood freezing-point determinations showed that over the salinity range 20-37^o/oo lobsters are able to osmoregulate to a limited extent only towards the lower end of the range, being otherwise an "osmo-conformer." Salt-loading experiments indicated that excess salts were rapidly excreted into the gut. It is concluded that antennal glands are at least partly responsible for elimination of excess water, but that gut is the site of salt excretion, and that there is rapid adjustment of salt imbalance.

716. Dall, W. 1974. Osmotic and ionic regulation in the western rock lobster, *Panulirus longipes*. Jour. Exper. Mar. Biol. Ecol. 15:97-125.

The western rock lobster is poikilosmotic over its tolerated salinity range of 25-45^{o}/oo. Blood Na is accumulated while chloride concentration is reduced. Na and chloride vary directly with the external salinity, although maintaining their differences in the same proportions as at normal salinity (36.0^{o}/oo). Ca is accumulated, ranging from over 150% at salinity 20^{o}/oo to about 117% at salinity 45^{o}/oo. K concentration is equivalent to the external at normal salinity, but is increased with lowered and decreased with raised salinity. Mg is reduced to about one-third that of the external concentration over the salinity range 20-40^{o}/oo, but regulation begins to break down at 45^{o}/oo. Individual ions exhibit, therefore, a range of regulation types, from poikilosmotic to homoiosmotic.

Equilibrium for Na, Cl, and Ca is attained in 10 h at salinities of 25, 30, 40, and 45^{o}/oo, respectively. Rate constants for this exchange are linearly related to salinity differential, and rapid osmotic adjustment is by high permeability, equal in both directions, probably mainly via the gills. Muscle appears to act as a salt pool for Na, Cl, and K but not for Mg and Ca. Salt-loading causes a slight salt diuresis, the salts being excreted, probably via the gills. Except for Ca, there is no excretion of salt into the gut, but there is evidence of an exchange of chloride with another anion. Magnesium excretion is slow, and in the absence of osmotic stress possibly occurs via the antennal glands. All the ions examined appear to be regulated independently.

717. D'Amelio, V., G. Russo, and D. Ferraro. 1974. The effect of heavy metal on protein synthesis in crustaceans and fish. Rev. Intern. Océanogr. Médicale 33:111-118.

A technique is described to obtain polyribosomal profiles from the hepatopancreas of *Eriphia spinifrons* and their role in protein synthesis demonstrated. During the acclimitization of crustaceans in sea water containing lead, polyribosomes disappear from the profile.

Studies were also conducted on blood cells from goldfish, *Carassius auratus*, including lead-induced changes in cell density; hemoglobin (Hb) synthesis; and aminolevilinic acid dehydrase (ALA dehydrase). Results indicate that owing to the large variability in cell density, present also in the untreated animals, only data obtained on statistical bases may show changes of cell density.

Hb synthesis is strongly inhibited by lead and ALA dehydrase activity is also reduced during immersion in 0.2 mg Pb^{2+}/1 for 5 days.

718. Davenport, J. 1972. Salinity tolerance and preference in the porcelain crabs, Porcellana platycheles and Porcellana longicornis. Marine Behav. Physiol. 1:123-138.

P. platycheles was found to be euryhaline while the related P. longicornis proved to be stenohaline. Prior acclimation to 60% s.w. improved survival in 40% s.w. in P. platycheles. Salinity preference was demonstrated in P. platycheles, which could avoid low salinities and move along salinity gradients to do so; at high salinities the Weber-Fechner "law" may operate for this crab as it could avoid high salinities but could not differentiate between two high salinities, separated by 3.4°/oo. P. platycheles differentiated between solutions on the basis of their total osmolarities, and the ability to do so was significantly impaired by removal of the antennules. P. longicornis exhibited no ability to distinguish between salinity levels.

719. Davenport, J. 1972. Effects of size upon salinity tolerance and volume regulation in the hermit crab, Pagurus bernhardus. Marine Biology 17:222-227.

Experiments were carried out to assess salinity tolerance and ability to regulate body volume in a dilute medium, of small and large hermit crabs. Large, offshore hermit crabs are significantly less tolerant of 60% sea water (100% = 34°/oo S) than small, littoral specimens. Small littoral crabs increase in weight by about 15% in the first hour in 60% sea water, but increased urine output prevents swelling thereafter; indeed, there is considerable loss in weight, presumably caused by solute loss. Large, offshore crabs increase in weight by about 15% in the first hour, thus exhibiting a higher permeability to water than small crabs, and continue to increase in weight, since urine output is not sufficient to cope with the water load. The nephropores of large hermit crabs are too small to allow a sufficiently high urine output to remove a large water load, unless greater pressures are developed inside the excretory systems of large hermit crabs than occur in those of small littoral individuals. It is concluded that the stenohalinity of large, offshore hermit crabs may exclude them from the littoral zone, or may be the result of exclusion by other factors since there will be no selective advantage for large hermit crabs in maintaining the degree of euryhalinity possessed by the small littoral crabs, if the large crabs are confined to the sublittoral zone.

720. Davey, E.W., M.J. Morgan, and S.J. Erickson. 1973. A biological measurement of the copper complexation capacity of seawater. Limnology and Oceanography 18(6):993-997.

Copper titrations of known concentrations of chelators in artificial seawater illustrated that the growth depression of the alga, *Thalassiosira pseudonana* in response to copper could be used to quantitate the chelator levels to within ±5% at concentrations down to 10^{-7} M EDTA. These results suggest that measured variations in *T. pseudonana* --copper bioassays to samples from Narragansett Bay, Rhode Island, and vicinity--could be due to organic chelators in seawater.

721. Davies, A.G. 1970. Iron, chelation and the growth of marine phytoplankton. I. Growth kinetics and chlorophyll production in cultures of the euryhaline flagellate *Dunalliela tertiolecta* under iron-limiting conditions. Jour. Mar. Biol. Assn. U.K. 50:65-86.

By using an apparatus designed to permit the rotation of the culture vessels, it was found possible to reduce the concentrations of iron, as hydrous ferric oxide, in cultures to levels which restricted growth of plant cells, as, under these conditions, much of the oxide adhered to the vessel. At the lowest iron concentrations, growth rate was eventually controlled by rate of detachment of oxide from the vessel and cells then contained the minimal level of iron which would allow growth to continue. This minimal level was found to decrease cells in the iron-deficient stock cultures adapted to the medium. The concentrations of residual iron, not removed from sea water in the culture medium by filtration through a 0.1 μm pore-size membrane filter, were shown to be similar to those of the added iron in certain cases, and had therefore to be included in the total iron available for growth. Using a chelating agent to fractionate the iron associated with the cells, it was possible to estimate the metabolically bound iron. The rates of growth were found to be related to this metabolic iron by a hyperbolic expression. Rate constants obtained using the expression were in good agreement with those observed directly in cultures where iron concentrations were sufficient to permit exponential growth. Chlorophyll a production by cells was largely dependent upon that fraction of the metabolic iron which was supplied by residual iron, the added form being much less effective in this respect and suggests that chlorophyll production in phytoplankton may require the presence of organo-iron complexes.

722. Davies, A.G. 1973. The kinetics of and a preliminary model for the uptake of radio-zinc by *Phaeodactylum tricornutum* in culture. *In* Radioactive Contamination of the Marine Environment, Int. Atom. Ener. Agen., Vienna, Austria: 403-420.

Using Zn 65-labelling, measurements of the rate of uptake of zinc ions by initially zinc-free cells, have been made. Treatment of a suspension of cells, containing zinc with a chelating agent indicates that a portion of the metal associated with the cells is loosely bound and probably adsorbed on to the cell surface. The remainder of the metal in the cell is more firmly based; in the early stages of uptake, it increases linearly with the square root of time and this has been taken to indicate that the uptake of the metal is passive and diffusion controlled. The metabolic zinc content of the cells later passes through a maximum despite the availability of further zinc for uptake and then gradually decreases. This has been interpreted as being due to a reduction in the number of zinc-binding sites (probably protein) within the cells, as they progress through their growth cycle. A simplified model of these events, capable of computerization, has been developed and tested against the experimental observations.

723. Davies, P.H., and W.H. Everhart. 1973. Effects of chemical variations in aquatic environments: Vol. III, Lead toxicity to rainbow trout and testing application factor concept. U.S. Environ. Protect. Agen. Rept., EPA-R3-73-011c:1-80.

Four chronic bioassays were conducted to determine the toxicity of lead to rainbow trout. Results obtained from acute and chronic bioassays in hard water (alkalinity 243.1 mg/l) and soft water (alkalinity 26.4 mg/l) were used to test the application factor approach as related to different water qualities. The toxicity of lead to rainbow trout in hard water was determined on a total and dissolved lead basis. The 96-hr LC-50 and MATC (Max. Accept. Toxicant Conc.) on a total lead basis were 471 mg/l and 0.12 to 0.36 mg/l respectively, which yielded an application factor of .0002 to .0008. Analysis of the free or dissolved lead gave a 96-hr LC-50 of 1.38 mg/l and a MATC of 0.018 to 0.032 mg/l, resulting in an application factor of .0130 to .0232. Total and free lead were considered to be the same in soft water. The LC-50 (18 d) and MATC obtained from soft water bioassays were 140 μg/l and 6.0 to 11.9 μg/l lead respectively. Computations using the LC-50 and MATC values gave a soft water application factor of .0429 to .0850. The MATC was determined in both hard and soft water bioassays on the occurrence of abnormal black tails and caused by chronic lead exposure. The application factor approach as related to different water qualities was found to be very promising when lead analysis was limited to the free or dissolved metal and failed when total hard water lead concentrations were used.

724. Davis, T.R.A., A.W. Burg, K.M. Butters, and B.D. Wadler. 1971. Water quality Criteria Data Book, Vol. 2: Inorganic chemical pollution of freshwater. U.S. Environ. Protect. Agen. Rept. 18010 DPV:1-280.

A survey of the literature dealing with inorganic chemical compounds was conducted to obtain and reference data relevant to the establishment of water quality criteria. More than 5,000 publications were reviewed. While nearly 300 inorganic chemical species may exist in freshwater only 87 were identified in the literature. A wide distribution of concentrations in potable and polluted water was found.

Data on acute toxicity, chronic toxicity, carcinogenicity, mutagenicity, and teratogenicity of inorganic chemicals to aquatic organisms have been tabulated. Because of the design of most of these toxicological determinations, it is difficult to extrapolate from this data to human health. This inability is furthered in that the concentrations of many materials in freshwater are reported in terms of elemental analysis alone without reference to the ionic or complex form of the material. However, toxicity varies with the complex ion and oxidation state.

Correlations have been made of minimum lethal oral dose versus maximum concentrations reported in freshwater, and of minimum chronic toxic dose versus maximum concentration reported in drinking water. Examples of inorganic species which approach a safety limit have been observed.

725. Davis, P.W., and G.A. Wedemeyer. 1971. Na^+, K^+-activated-ATPase inhibition of rainbow trout: a site for organochlorine-pesticide toxicity. Comp. Biochem. Physiol. 40(3B):823-827.

The Na^+, K^+-activated, Mg^{2+}-dependent-ATPase enzyme system in a heavy microsomal fraction of rainbow trout (*Salmo gairdneri*) brain was inhibited *in vitro* by chlorinated hydrocarbon pesticides. Similar inhibition by these pesticides occurred in kidney and gill ATPase preparations. An unexpected finding was a failure of the classic inhibitor, ouabain, to block the Na^+, K^+-activated component of ATPase activity in the gill. It is suggested that inhibition of ATPase activity may be a causal factor in the toxic effects of organochlorine pesticides in fishes.

726. Dean, J.M. 1974. The accumulation of ^{65}Zn and other radionuclides by tubificid worms. Hydrobiologia 45(1):33-38.

Tubificid worms did not accumulate radionuclides bound to sediments, but did accumulate dissolved radionuclides. The level of accumulation of dissolved ^{65}Zn by the worms was dependent upon temperature and concentration of the radionuclide.

727. Dean, R.B. 1972. The case against mercury. Available from Nat. Tech. Inf. Serv., Springfield, Va., as PB-213-692:1-11.

The toxicity of mercury is increased more than tenfold when it is converted to methylmercury which destroys nerves in the brain and advances senility. Bacteria convert mercury in aquatic sediments into methylmercury which is concentrated by predatory fish. The historical background of mercury pollution is presented, followed by a discussion of the best methods for mercury detection, means by which mercury enters the environment, standards, and Environmental Protection Agency enforcement.

728. Decleir, W., J. Lemaire, and A. Richard. 1970. Determination of copper in embryos and very young specimens of Sepia officinalis. Marine Biology 5:256-258.

The total amount of copper in embryos and newly hatched young individuals of Sepia officinalis L. (a decapod mollusc) has been determined by microtechnique, using bathocuproine-sulfonate as complexing reagent. During embryonic life, the total amount of copper does not change; it remains at a level close to 3.8 μg. The copper is found in the yolk sac of very early embryos; it is subsequently transferred into the embryo proper. After hatching, the copper content diminishes quickly in starved individuals. Fed S. officinalis also usually lose copper. The reason for this may be that the inner yolk sac of newly hatched individuals contains a great deal of the total copper, which is excreted with the yolk after the latter has become superfluous. Later on, copper must be taken up from the food. The mobilization of protein and copper from the yolk into the blood may account for the early appearance of embryonic hemocyanin in the blood.

729. DeCoursey, P.J., and W.B. Vernberg. 1972. Effect of mercury on survival, metabolism and behavior of larval Uca pugilator (Brachyura). Oikos 23:241-247.

Effects of three dilute mercuric chloride solutions on larval stages (Zoea I, III, V) of the fiddler crab Uca pugilator were determined. The influence of both acute and chronic exposures on viability, oxygen consumption, and swimming activity was measured. No stage V and only a few stage I or III larvae were able to survive a concentration of 9×10^{-7} M $HgCl_2$ (0.18 mg/l Hg) longer than 24 hr; an exposure as short as 6 hr resulted in reduced metabolism and swimming rate of all stages. Although concentrations of 9×10^{-9} M $HgCl_2$ (0.0018 mg/l) and 9×10^{-11} M $HgCl_2$ (0.000018 mg/l) were sublethal, 24-hr exposures did affect metabolism and swimming. Some larvae reared in the more dilute mercury solutions developed to the megalops stage, but survival was reduced in relation to the mercury concentration. Data from all tests suggest that toxicity of mercury increases with larval age.

730. De Goeij, J.J.M., and C. Zegers. 1971. Mercury in fish--imported tinned fish. TNO-nieuws 26:400-401.

Total mercury in canned fish purchased at a department store of the six most commonly consumed species imported from several countries in Europe, the Americas and Asia was determined by neutron activation analysis; methyl mercury was determined by means of gas chromatography. Mercury content ranged from 0.01 to 0.1 mg/kg in salmon, mackerel, herring and sardines. Tuna showed a range of 0.032 to 1.0 mg/kg Hg; methyl mercury constituted 80% of total mercury. The country of origin did not influence the mercury content and there was no accumulation in any particular organ in excess of the contents in the meat tissue.

731. Dehlinger, P., W.F. Fitzgerald, S.Y. Feng, D.F. Paskausky, R.W. Garvine, and W.F. Bohlen. 1973. Determination of budgets of heavy metal wastes in Long Island Sound, Annual Report, Parts I & II. Univ. Connecticut, Marine Sciences Institute, Groton Conn.

Investigations of heavy metal wastes in Long Island Sound are reported for the first year of effort of a longer term program. The study consists of five integrated projects on: the fates and concentrations of heavy metals in the water column; concentrations and effects of these metals in oysters; water circulation patterns which control water renewal times and flushing rates; structure and motion of Connecticut River outflow into the Sound; and transport of suspended materials in the Sound. Emphasis during this first year was on the eastern Sound.

The following was determined during the first year.

1. The eastern region of the Sound is so effectively flushed by tidally driven currents that any material entering will be efficiently mixed and removed by water circulation within a few days time. The eastern Sound is therefore not a sink for heavy metal wastes.

2. Circulation patterns appear to exist in the eastern Sound which are highly variable. Whatever the patterns of the tidal circulations in the eastern sound, we know that they are not simple back and forth tidal motions as had been previously thought, but that there is a considerable net drift for each cycle.

3. The outflow of the Connecticut River is manifested as a distinct plume having sharp boundaries or fronts and being only a few meters in depth. During flood tide the plume usually extends westward along the Connecticut coast; during ebb tide the plume usually extends southeasterly, toward Plum Island and the passages in the eastern Sound. Connecticut River water appears to be flushed within a few days from the Sound.

4. Mercury and copper in the water column of the eastern Sound are both organically and inorganically associated; lead also appears to have large fractions of organic components.

5. Suspended materials in the eastern Sound consist primarily of clays and organic matter. Concentrations of suspended materials in the open Sound are greater near the bottom than in surface waters. Sediment transport fluctuates greatly in response to storms.

6. Oysters at control stations along the Connecticut coast exhibited substantial uptake of Hg, Cu, Cd, Mn, Ni, and Zn. The uptake for all metals except Hg was greatest in the vicinity of the Housatonic River, along which metal fabrication plants are located. By contrast, the Hg uptake was greatest in the vicinity of the Mystic River, a development not yet explained. None of the metal concentrations appeared to be dangerous for human consumption. No significant differences in metal uptake could be correlated with season, despite large changes in oyster pumping rate with season. It is demonstrated that oysters can be used as a biological monitor of heavy metals in the bays and estuaries of Long Island Sound.

In this research a new laboratory technique was developed by which chemical fractions of mercury in trace amounts of sea water could be determined more accurately than was previously done. This made possible the detection or organically formed mercury in the water and thus provided a way for distinguishing mercury of organic from inorganic origin.

732. Dempster, R.P., and W.H. Shipman. 1969. The use of copper sulfate as a medicament for aquarium fishes and as an algaecide in marine mammal water systems. Occasion. Papers California Acad. Sciences, No. 71:1-6.

This paper describes the use of copper sulfate to control algae and fish ectoparasites in marine aquaria. The method introduced in this paper prevents copper precipitation in alkaline water, thus permitting copper ions to be maintained in solution. Copper compounds must be utilized with considerable caution since they are toxic to all forms of life. Therefore, a technique is given by which, once the concentration of copper in the water system is adjusted, sequestered copper is added at a rate sufficient to maintain the concentration. This procedure has been used for the last 15 years at the Steinhart Aquarium and as a result there has been no outbreak of fish disease. Copper concentrations up to 1 mg/l have been used.

733. D'Itri, F.M., C.S. Annett, and A.W. Fast. 1971. Comparison of mercury levels in an oligotrophic and a eutrophic lake. Marine Technol. Soc. Jour. 5(6):10-14.

Mercury analyses established that 59 rainbow trout taken from an oligotrophic Michigan lake contained an average total mercury concentration of 0.17 mg/kg. On the other hand, 100 trout from a eutrophic lake contained 0.07 mg/kg. The total mercury content of soils in the vicinity of the lakes is similar. However, sediments of Hemlock Lake contained significantly higher levels of mercury than those from Section Four Lake. Water samples taken from both lakes at various depths showed mercury levels of less than 0.1 μg/l, the limit of sensitivity for the analytical method that was used. The removal of mercury by adsorption onto organic particulate matter probably is a key factor in the different mercury levels of fish in the two lakes. It is this adsorption mechanism that makes the mercury from pollution less available for accumulation by the fish that feed in the water column. Therefore, the persistence of mercury compounds in these two isolated lakes appears to be related to the organic character of each lake. Accordingly, mercury pollution appears to pose a greater environmental hazard in oligotrophic than in eutrophic lakes.

734. Dolar, S.G., D.R. Keeny, and G. Chesters. 1971. Mercury accumulation by *Myriophyllum spicatum* L. Environmental Letters 1(3):191-193.

An investigation of the magnitude and rate of Hg accumulation by a rooted aquatic plant--*Myriophyllum spicatum* L. (watermilfoil)--from solution culture and from Hg-contaminated lake sediments was conducted. As determined by solution culture experiments, Hg accumulation was much greater with inorganic than organic Hg carriers. Mercury accumulation from nutrient solution was rapid and approached maximum values in 2 hours. Organomercury compounds were more available than inorganic compounds from lake sediments likely because of precipitation of inorganic Hg as sulfides. Mercury accumulates in rooted aquatic plants by physical adsorption and by metabolic uptake and translocation, the latter occurring mainly with organomercury compounds. Rooted aquatic plants might prove to be an important link in the uptake and cycling of Hg derived from contaminated sediments.

735. Domogalla, B. 1935. Eleven years of chemical treatment of the Madison Lakes: Its effect on fish and fish foods. Trans. Amer. Fish. Soc. 65:115-121.

After 11 years of scientific study and chemical treatment of lakes about Madison, Wisconsin, especially Lake Monona, author concludes that the spraying method of copper sulphate and other chemicals is most effective and economical in keeping obnoxious algae and certain fungi that parasitize fish under control; that spraying does not adversely affect rooted water weeds or zooplankton. However, weed cutting machines, steel cables, and arsenical compounds were necessary for removal of rooted water weeds around beaches and boathouses.

736. Domogalla, B. 1941. Scientific studies and chemical treatment of the Madison Lakes. A symposium on Hydrobiology, Univ. of Wisconsin Press, Madison: 303-309.

Studies of chemical treatments applied to the Madison Lakes indicated: (1) Spraying with copper sulphate and other chemical treatments was found to be the most effective and economical method of controlling growths of obnoxious algae and weeds. (2) Chemical treatments did not seriously injure the zooplankton. (3) Chemical treatments for control of algae also controlled Saprolegnia. (4) Chemical spraying also brought "Swimmer's Itch" and fungus infections under control. (5) Studies over an 18-yr period indicate that nitrogen, phosphorus, and bicarbonate compounds are among the factors that tend to promote the excessive growth of algae and large aquatic plants. Chemical treatment with copper sulphate reduced the numbers of algae in the Madison Lakes but did not eliminate them.

737. Donaldson, L.R., P.R. Olson, S. Olson, and Z.F. Short. 1971. Fern Lake Studies. Available from Nat. Tech. Inf. Serv., Springfield, Va., as RLO-2225-T-7-6:1-78.

Over a 14-year period, determinations were made of transfer coefficients of labeled P, K, and Ca in forest ecosystems and of concentration factors for radionuclide uptake by aquatic animals (I in fish thyroids, 1200; Mo in gills and livers, 3000-5000; Mo in periphyton, 9000-15000). The studies included mapping and characterization of soils; description of plant communities; quantitative evaluation of the vegetation; modelling of the nutrient status of plant associations; and the physical, chemical, and biological effects of Ca enrichment of the lake.

738. Downes, K.M. 1957. An investigation of manganese and zinc in the oyster Crassostrea virginica (Gmelin). Ph.D. Dissertation, Univ. Maryland, College Park, Md.: 1-54.

Oysters collected from 2 stations in Chesapeake Bay between July and November 1955 were analyzed for manganese and zinc content. Age determinations were made from the longitudinally sawed shells using "annual rings" as the index. Manganese content in oysters ranged from 0.3 mg per oyster to 25.4 mg per oyster. Zinc content ranged from 0.9 mg to 100.3 mg per oyster. Author concludes that no direct association of Zn or Mn was possible with either age or weight. However, zinc content showed closer association with both age and weight than manganese content.

739. Drummond, R.A., G.F. Olson, and A.R. Batterman. 1974. Cough response and uptake of mercury by brook trout, Salvelinus fontinalis, exposed to mercuric compounds at different hydrogen-ion concentrations. Trans. Amer. Fish. Soc. 103(2): 244-249.

The lowest concentration of methylmercuric chloride (MMC) and mercuric chloride added to Lake Superior water that caused a significant increase in cough frequency in brook trout was 3 μg Hg/liter. Cough frequency is a good short-term indicator of the long-term effects of MMC. The response can be used to predict the safe concentration of mercuric chloride since the long-term effects of this compound are not known. Increases in cough frequency were proportional to the concentration (from 3 to 12 μg Hg/liter) of both compounds at pH 7.5. The fish were more responsive to MMC when the pH of the test water was lowered to 6.0; response to mercuric chloride was not changed by lowered pH. Fish exposed to MMC at pH 6.0 contained more total mercury in their gills and red blood cells than fish tested at pH 9.0. The uptake of mercury by brook trout exposed to mercuric chloride did not differ significantly at pH 6.0 and 9.0.

740. Drummond, R.A., W.A. Spoor, and G.F. Olson. 1973. Some short-term indicators of sublethal effects of copper on brook trout, Salvelinus fontinalis. Jour. Fish. Res. Bd. Canada 30(5):698-701.

Laboratory tests were conducted to evaluate changes in cough frequency, locomotor activity, and feeding behavior as possible short-term indicators of the long-term effects of copper on brook trout. Tests were conducted in chambers that allowed free movement in continuously flowing water. The electrodes measured respiratory and other movements, which were recorded on a polygraph. The effect of copper on coughing was measured by comparing cough frequency during a 24-hour exposure to that during the preceding 24-hour period. The effect on locomotor activity was measured during the first 2 hours of exposure and compared with activity the day before the test and with that of controls. Feeding behavior was monitored at 2 and 24 hours after exposure began and any departure from normal agressive feeding patterns was recorded. Changes occurred in all three activities at copper concentrations near 0.5 micrograms/l. Each response thus showed promise as a short-term indicator of the concentration range at which chronic exposure might have no permanent effect. Cough frequency was the best of the three for showing stress according to the copper concentration, but the change developed more slowly than in locomotor activity.

741. Duce, R.A., J.G. Quinn, C.E. Olney, S.R. Piotrowicz, B.J. Ray, and T.L. Wade. 1972. Enrichment of heavy metals and organic compounds in the surface microlayer of Narragansett Bay, Rhode Island. Science 176(4031):161-163.

Concentrations of lead, iron, nickel, copper, fatty acids, hydrocarbons, and chlorinated hydrocarbons are enriched from 1.5 to 50 times in the top 100-150 micrometers of Narragansett Bay (Rhode Island) water relative to the bulk water 20 cm below the surface. Trace metal enrichment was observed in the particulate and organic fractions but not in the inorganic fraction. If these substances are concentrated in films only a few molecular layers thick on the water surface, the actual enrichment factor in the films may be well over 10,000 resulting in extremely high localized pollutant concentrations in the surface microlayer. Some implications of these findings are discussed, including bioaccumulation by plankton.

742. Dudnikov, V.F., and V.P. Mikheev. 1964. The effect of certain metal ions on Dreissena. Translated from Trudy Instituta Biologii Vnutrennikh Vod, No 7(10):

One method for the elimination of Dreissena (mollusca) overgrowth in pipelines is the use of electrolytically dissolved metal ions. Silver, copper, mercury, zinc and lead were tested for their molluscicidal effect. Copper is the most effective (100% mortality in 24 hours at 4 mg/l). Larger molluscs die sooner than small ones. Dreissena perish sooner at water temperature optimal for their development.

743. Dunson, W.A., and G.W. Ehlert. 1971. Effects of temperature, salinity, and surface water flow on distribution of the sea snake Pelamis. Limnology and Oceanography 16(6):845-853.

The pelagic yellow-bellied sea snake *Pelamis platurus* is a surface feeder which apparently drifts passively with surface currents. In areas of horizontally convergent surface water flows, hundreds or even thousands of *Pelamis* are concentrated in slicks, apparently characteristic members of a community of organisms associated with slicks.

The distribution of *Pelamis* in the tropical Indian and Pacific Oceans is correlated with surface temperatures; colonization of the Atlantic Ocean has likely been prevented by low surface temperatures off the tips of South Africa and South America. Breeding populations apparently occur only in areas in which mean monthly temperatures exceed 20°C. The upper lethal temperature of *Pelamis* is about 33°C. Thermoregulatory diving may be a mechanism of avoiding heat depth in tropical seas where surface water temperatures reach 31°C and insolation is intense. *Pelamis* can survive in freshwater for periods longer than 6 months.

744. Dushkina, L.A. 1973. Influence of salinity on eggs, sperm and larvae of low-vertebral herring reproducing in the coastal waters of the Soviet Union. Marine Biology 19:210-223.

Clupea harengus pallasi spawn in the coastal zone where salinity is one of the more variable factors. Observations were gathered in the field from seas of the European North and Far East, and in laboratory experiments where salinities varied from 0 to 70^{o}/oo, on influence of salinity on development of herring eggs. Eggs from numerous populations of Pacific herring are capable of fertilization over a wide range of salinities, however some geographic races of herring exhibit a marked population specificity. For example, eggs from *C. harengus pallasi* differ from those of *C. harengus harengus*: osmotic resistance of eggs to low salinities is considerably higher in the first-mentioned subspecies. Under salinity stress, eggs reveal individual differences which are not seen under optimum conditions of salinity.

745. Eaton, J.G. 1973. Chronic toxicity of a copper, cadmium and zinc mixture to the fathead minnow (*Pimephales promelas* Rafinesque). Water Research 7(11):1723-1736.

Fathead minnows were exposed to a series of concentrations of a copper, cadmium and zinc mixture during a 12.5 month chronic test in water of 200 mg/l total hardness. The metal concentrations in the mixture were selected on the basis of results obtained during previous chronic exposures to each of the metals individually in the same water. Strict summation of the chronic toxicities of the metals was not indicated when they were tested in combination. Toxic effects of the mixture attributable to copper appeared to be increased, but that attributable to cadmium was reduced. The effects thought to be due to zinc were similar in degree to those observed in the single chronic exposure. Summation of effects resulting from a mixture containing about the same proportions of copper, cadmium and zinc occurred at a much higher, acutely lethal concentration. A lethal threshold was attained in the mixture when each metal was present at a concentration of 0.4 or less of its individual lethal threshold.

746. Eaton, J.G. 1974. Chronic cadmium toxicity to the bluegill (*Lepomis macrochirus* Rafinesque). Trans. Amer. Fish. Soc. 103(4):729-735.

Nine out of 18 adult bluegills exposed for 11 months during a chronic bioassay which included effects on reproduction, were killed at 80 µg/l of cadmium in water of 200 mg/l (as $CaCO_3$) hardness. Progeny exposed for 30 days were killed at 90 µg/l. Adult fish spawned at 239 µg/l and at 2,140 µg/l, but most larvae were severely crippled 6 days after hatching at these concentrations. No effects on survival, development, or reproduction were attributable to cadmium at 31 µg/l. The highest tissue residues were found in liver, intestine and caecum, and kidney. Cadmium concentrations increased with exposure concentration in gill, liver, and intestine and caecum, but not in kidney. Until more information is available on cadmium toxicity in different water types, chronically toxic and "just safe" continuous exposure concentrations probably can be estimated better by relatively short-term exposures of embryos and larvae than by the use of application factors.

747. Edgington, D.N., S.A. Gordon, M.M. Thommes, and L.R. Almodovar. 1970. The concentration of radium, thorium, and uranium by tropical marine algae. Limnology and Oceanography 15(6): 945-955.

Twenty species of marine algae were collected between 1961 and 1968 from coastal waters of Puerto Rico and analyzed chemically for total organic material, protein nitrogen, and calcium, and radiochemically for the naturally occurring alpha particle emitters ^{226}Ra, ^{232}Th, and ^{238}U. Study of these data suggests that the concentration of radium, thorium, and uranium by tropical marine algae is controlled by two mechanisms: 1) ion-exchange or coprecipitation of the ion with the calcium carbonate matrix, and 2) complex formation with either the protein nitrogen or some other component of the organic fraction. Radium (and possibly thorium) apparently is concentrated by both mechanisms. For the Rhodophyta and the highly calcified Chlorophyta it is 1) and for the Phaeophyta 2). Uranium is concentrated by the first mechanism.

748. Eipper, A.W. 1959. Effects of five herbicides on farm pond plants and fish. N.Y. Fish Game Jour. 6(1):46-56.

Data obtained from applications of five different herbicides in central New York farm ponds over a 3-year period are summarized. Delrad, Fermate, Phygon-XL, copper sulfate, and sodium arsenite were the chemicals employed. Available information deals chiefly with effects of these herbicides on algae, submersed aquatics, and various sizes and species of fish in 30 farm ponds which received a total of 70 herbicide applications. Ranges in physical-chemical determinations in 16 of these ponds were: pH, 7.6-8.8; total alkalinity, 60-170 mg/l; surface water temperature, 17-27°C; and bottom temperature, 15-26°C. When applied as surface sprays to produce a pondwater concentration of 0.5 mg/l active ingredient by weight, Delrad, Fermate, and copper sulfate were all equally effective in controlling unbranched filamentous green algae. With respect to treatment cost and safety of small fish, copper sulfate had definite advantages over Delrad or Fermate. Tests of Phygon in seven ponds were inconclusive, indicating only that 0.25 mg/l concentrations of this chemical killed neither fish nor plant growths. Sodium arsenite at 4 mg/l controlled *Hydrodictyon* and *Cladophora* (branched algae little affected by the other chemicals tested), as well as other algae and various submersed rooted aquatics in 10 ponds.

749. Eisler, R. 1972. Pesticide-induced stress profiles. *In* Ruivo, M. (ed.). Marine Pollution and Sea Life, Fishing Trading News (books) Ltd., London: 229-233.

Results of acute toxicity bioassays with selected organochlorine and organophosphorous insecticides and various species of marine teleosts, crustaceans, and molluscs are summarized; physicochemical factors known to affect mortality patterns are listed. A profile technique is developed to evaluate effects of sublethal levels of pesticides to marine fauna, and is based on the hypothesis that metabolic disturbances have a far greater probability of detection if a number of parameters are simultaneously determined and plotted. Examples are presented of pesticide-induced stress in selected marine species utilizing as parameters hemoglobin, serum proteins, esterases, and other blood constituents, concentrations of Zn, Ca, Mg, Sr, K and Na in selected tissues and whole animals. Visual patterns that are produced by these profiles afford an index useful for identification of unfavorable environmental conditions before obvious morphological or physiological changes occur. Ultimately, it could become feasible to correlate specific profiles with individual toxic agents.

750. Eisler, R. 1973. Annotated bibliography on biological effects of metals in aquatic environments. U.S. Environ. Protect. Agen. Rept. EPA-R3-007:1-287.

A total of 567 references on biological effects of metals to aquatic organisms were annotated and subsequently indexed by metal and by taxa. Preference was given to articles on toxicity of heavy metals to marine, estuarine, and anadromous species.

751. Eisler, R. 1974. Radiocadmium exchange with seawater by *Fundulus heteroclitus* (L.) (Pisces: Cyprinodontidae). Jour. Fish Biol. 6:601-612.

Mummichogs, *Fundulus heteroclitus*, accumulated Cd 115m $(NO_3)_2$ from synthetic seawater solutions during a period of 25 days, but the rate of whole body accumulation decreased with increasing concentrations of stable Cd^{2+} in the medium. Viscera were the major repository of Cd 115m during uptake, especially gastrointestinal tract and to a lesser extent liver. Loss in whole body radioactivity over a post-treatment interval of 180 days in cadmium-free seawater was about 90%, with gallbladder and especially liver most influential in the excretion processes; this pattern was unchanged by the level of stable Cd^{2+} present in the medium during uptake. Concentration factors for divalent salts of several metals and mummichogs at 96 hours were determined. On the basis of highest sublethal levels tested, values were 11.1 for Zn, 0.66 for Be, 0.17 for Cd, 0.09 for Co, 0.07 for Ni, and 0.00 for Cu. The significance of these and other observations in terms of field monitoring of cadmium utilizing teleosts as indicators is discussed.

752. Eisler, R., and G.R. Gardner. 1973. Acute toxicology to an estuarine teleost of mixtures of cadmium, copper and zinc salts. Jour. Fish Biol. 5:131-142.

Effects of mixtures of chloride salts of cadmium, copper and zinc on survival, whole body residues, and histopathology of mummichog, *Fundulus heteroclitus*, were investigated in synthetic seawater at 20^{o}/oo salinity and 20°C. Mixtures of Cu^{2+} and Zn^{2+} as indicated by 96 h bioassay studies produced more deaths than expected on the basis of toxicities of individual components. Concentrations of Cd^{2+} not ordinarily lethal exerted a negative effect on survival of fish intoxicated by salts of copper, zinc, or both.

Atomic absorption determinations of Cd, Cu, and Zn residues in mummichogs which survived 96 h exposures to each of these toxicants provided useful indices of total body burdens for these metals. Residues from survivors held in mixtures, especially Cd^{2+} and Zn^{2+} mixtures, did not conform to patterns observed for single elements. Whole body aggregates of Cd, Cu, and Zn from dead mummichogs were of limited worth owing to possible accumulation of these metals from the medium after death.

Renal and lateral line canal lesions were noted in all fish subjected to copper concentrations of 1 mg/l and higher. Renal lesions observed in fish immersed in mixtures of Cu^{2+} and Cd^{2+} assumed a damage pattern characteristic of Cd^{2+}; with mixtures of Cu^{2+} and Zn^{2+}, lesions were typical of Cu^{2+} induced damage. Lesions induced in lateral line epithelium by Cu^{2+} were not affected by either Cd^{2+} or Zn^{2+}. Epithelia lining the oral cavity were necrotized by the caustic action of high levels of Zn^{2+} (60 mg/l) and Cu^{2+} (8 mg/l).

753. Eisler, R., G.R. Gardner, R.J. Hennekey, G. LaRoche, D.F. Walsh, and P.P. Yevich. 1972. Acute toxicology of sodium nitrilotriacetic acid (NTA) and NTA-containing detergents to marine organisms. Water Research 6:1009-1027.

Static acute toxicity tests were conducted at 20°C and 20^{o}/oo salinity with $(CH_2COONa)_3\ N{\cdot}H_2O$ (NTA) and two NTA-containing commercial household synthetic detergents (syndets), using adults or juveniles from eleven species of marine fishes and invertebrates. Concentrations of NTA in the medium allowing 50% survival of individual test species in 168 h, = LC-50 (168 h) values, ranged between 1800 mg/l for grass shrimp, Palaemonetes vulgaris, and > 10,000 mg/l for quahaug clam, Mercenaria mercenaria. The two syndets tested were considerably more toxic than NTA to marine organisms under identical assay conditions. Fishes were the least resistant group of organisms tested to syndets; LC-50 (168 h) values for teleosts ranged between 4.6 and 36.0 mg/l total packaged product.

The effect of biomass, water temperature and salinity on acute toxicity of NTA and syndets to the killifish Fundulus heteroclitus was investigated. Increasing the biomass between 0.5 and 10.0 g/l of test medium was associated with increasing survival at any given concentration of syndet during a 48 h period; the reverse was observed for NTA. Within the salinity range 5-35^{o}/oo, mummichogs were most sensitive to NTA at comparatively low salinities; but syndets were most toxic at higher salinities. Water temperatures of 5° and 20°C had negligible influence on NTA- or syndet-induced mortality patterns. Mixtures of NTA and salts of cadmium or mercury were evaluated for toxicity to mummichog. An observed decrease in biocidal properties of Cd^{2+} was observed with increasing levels of NTA; concentrations as low as 10 mg/l NTA effected a measurable depression in Cd^{2+} lethality. Results of studies with NTA-Hg^{2+} mixtures were inconclusive. Tests with mixtures of syndet and Cd^{2+} or Hg^{2+} demonstrated that toxicity to mummichog of these mixtures could be expressed as a simple summation of the toxicity of individual components.

It is concluded that NTA might be hazardous to marine fishes and macroinvertebrates when used as a partial replacement for sodium tripolyphosphate in household syndets.

754. Eisler, R., and G. LaRoche. 1972. Elemental composition of the estuarine teleost Fundulus heteroclitus (L.). Jour. Exp. Mar. Biol. Ecol. 9(1):29-42.

Elements that were consistently present in whole ashed Fundulus heteroclitus as determined by atomic absorption were Ca, Cu, Fe, K, Mg, Mn, Na, Sr, and Zn; not measurable were Ag, Al, Au, Ba, Be, Cd, Co, Cr, Cs, Li, Ni, Pb, Rb, and Tl. This pattern was not affected by the age of the fish, its sexual condition, or the season of collection. Changes in whole body content of selected elements were observed with increasing age: in the range between 46 and 118 mm total body length, large fish contained more Ca and Sr and less K, Mg, Na, and Zn than small fish; Fundulus intermediate in size exhibited intermediate values for these elements. On an ash weight basis, heads were comparatively low in K, Fe, Mg, Zn, and Sr and carcasses comparatively high in K and low in Cu, Fe, Sr, and Na. Viscera contained high concentrations of most elements when compared with heads and carcasses, especially Fe, Zn, Sr, and Cu.

In a study of the effect on whole body elemental content of two size ranges of Fundulus, at two water temperatures, two salinities, and two acclimatization periods, authors found that Fundulus 84 mm in length contained more Ca, and less Cu, K, Mg, Na, and Zn per unit weight than those measuring 47 mm. Within each size group, fish kept at 5 or 20°C at salinities of 9°/oo or 27°/oo exhibited essentially the same elemental composition after 30 days; however, fish held for 30 days when compared with those held for only three days contained significantly less Ca, Na, K, Mg, Zn, Cu, and Mn.

In another study on effects of three seawater formulations, two feeding frequencies, and two medium replacement rates on whole body elemental composition, changes were least pronounced during a 30-day period among fish that were fed daily as compared with weekly, that were held in a seawater formulation developed by authors' laboratory as compared with natural seawater or a commercial preparation, and among groups with the medium replaced twice weekly compared with no replacement.

Selected data on the elemental composition of other species of teleosts and elasmobranchs are presented and discussed.

755. Eisler, R., G.E. Zaroogian, and R.J. Hennekey. 1972. Cadmium uptake by marine organisms. Jour. Fish. Res. Bd. Canada 29: 1367-1369.

Adults of killifish Fundulus heteroclitus, scallop Aquipecten irradians, oyster Crassostrea virginica, and subadult lobsters Homarus americanus were immersed for 21 days in flowing seawater containing 10 µg/liter of cadmium as $CdCl_2 \cdot 2\frac{1}{2}H_2O$. Cadmium residues in whole animals and selected tissues were consistently higher in exposed organisms than controls; edible portions of treated lobster (muscle), scallop (adductor muscle), and oyster (whole animal) contained more cadmium per unit wet weight than controls by 25%, 19%, and 352%, respectively.

756. England, R.H., and K.B. Cumming. 1971. Stream damage from manganese strip-mining. In Proc. 25th Annual Conf. Southeastern Assoc. Game and Fish Comm.: 399-418.

Abandoned manganese strip mines in Smyth County, Virginia have for many years discharged effluents to streams draining them. Manganese levels in all streams sampled were found to be below one mg/l. A controlled experiment with $Mn(NO_3)_2$ showed that the median tolerance limit for rainbow trout fingerlings is about 16 mg/l of Mn, which, together with stream sampling data, indicates that manganese is not present in toxic concentrations in the study streams.

Killinger Creek, which drains a partially reclaimed area, was found to support fewer species of fish and benthic fauna than Crigger Creek, a comparable control stream. Siltation is probably the main contributing factor. Bedload was much greater in affected streams than in control streams. Although volume of bedload was high in Blue Spring Creek, which drains a reclaimed area, particle size distribution of the bedload indicates that much of the finest silt has been flushed from the upper portion of this stream. Blue Spring Creek supports an abundant population of aquatic insects and fish fauna, indicating that reclamation has been effective on this watershed. It is also found that rainbow trout are spawning successfully in this stream.

Abandoned strip mines within the Cripple Creek study area have caused silt pollution in several streams. No evidence was found to support the theory that manganese ions were in solution in toxic concentrations to the endemic stream biota. Siltation was evident on Cripple Creek and two tributaries. Siltation was evident in Blue Spring Creek, which drained a fully reclaimed area, but there were no signs of recovery; turbidity compared with control streams, and bedload data indicated that much of the finer silt has washed out of the upper portion of the stream. High production of benthic organisms and evidence of trout spawning further indicate that reclamation has been very effective.

Killinger Creek, although it drained an area that was more than half reclaimed, showed striking evidence of siltation. Benthic production dropped sharply below the mined areas and game fish were entirely absent, while turbidity and bedload increased sharply.

757. Erickson, S.J. 1972. Toxicity of copper to *Thalassiosira pseudonana* in unenriched inshore seawater. *Jour. Phycology 8(4):318-323.*

Toxicity of copper to *T. pseudonana* (formerly *Cyclotella nana*, clone 13-1) was examined *in inshore seawater using a 96-hour bioassay* method. Raw unenriched seawater was filtered through a 0.22-micron membrane filter and then pasteurized for 30 min at 60°C. Following this treatment, samples contained 0.68-1.14 μg/l of Cu. Copper was added as the chloride in 5 μg increments over the range of 5 to 30 μg/l (about 0.1-0.5 microM). Population densities, mean cell volume, and C-14 bicarbonate uptake were measured. Population growth and C-14 uptake by *T. pseudonana* displayed inhibition over the entire range of added *copper. Growth rate* constant (k) to *T. pseudonana* decreased with increasing copper concentration and *during the course* of growth at each concentration. Correspondingly, mean cell volumes increased with copper concentration and time. Copper toxicity varied in different water samples. The presence of decomposed natural plankton and detritus decreased toxicity. In the absence of enrichment, bacteria had little effect on copper toxicity. Results were influenced by glassware treatment, collection and storage of seawater, and absence of enrichment.

758. Essig, T.H., G.W.R. Endres, J.K. Soldat, and J.F. Honstead. 1973. Concentrations of ^{65}Zn in marine foodstuffs and Pacific coastal residents. *In* Radioactive Contamination of the Marine Environment, Int. Atom. Ener. Agen., Vienna, Austria: 651-668.

One of the radionuclides formed by neutron activation in Hanford production reactors and released to the Columbia River in the effluent cooling water prior to February 1971 was Zn-65. Zn-65 has a relatively long radioactive half-life (245 days) and is an isotope of an element utilized in metabolic processes by most shellfish and other aquatic life forms. Consequently, Zn-65 is found in fish and shellfish in the Columbia River and in the Pacific Ocean near the mouth of the river. The transfer of Zn-65 through various food chains to man has been studied at Hanford for a number of years. In the present study, consumption rates of four seafoods were obtained for residents of two coastal communities. These consumption rates were used, together with concentrations of Zn-65 in the foods of interest, to estimate body burdens of Zn-65. The estimated body burdens were then compared with body burdens determined by whole-body counting techniques.

759. Evans, E.C. III, T.J. Peeling, A.E. Murchison, and Q.D. Stephen-Hassard. 1972. A proximate biological survey of Pearl Harbor, Oahu. Available from Nat. Tech. Inf. Ser., Springfield, Va., as AD-744 233. Rep. NUC TP 290:1-65.

During May and June, 1971, a biological survey of Pearl Harbor was conducted, in order to determine heavy metal (Cd, Cu, Hg, Pb, and Zn) body burdens for endemic marine organisms. In addition, the general aspect of piling communities in all major lochs is described and schematically illustrated, constituting the only such description for the region in nearly three decades. It was found that the body burdens of Cd, Hg, and Pb in fishes and crabs from Pearl Harbor tend to be higher near known sources of industrial effluent. Hg and Pb slightly exceed concentrations normally expected in marine animals; the burdens in swimming crabs tend to be highest (0.395 mg/kg wet weight for Hg and 1.8 mg/kg wet weight for Pb). For Cu and Zn, burdens tend to be greatest near Ford Island. Cu content of some swimming crabs exceeded that normally expected in marine animals (highest burden found was 241 mg/kg wet weight). None of these burdens, however, is considered cause for concern. The distinct differences observed in the structure of piling communities in the various lochs suggest that many complex environmental factors are at work in Pearl Harbor. While the detrimental effects of oil exposure are evident in the intertidal communities in all lochs, the major degrading factor to the marine environment as a whole appears to be silt. Water clarity and relative marine community health are greatest in those parts of the harbor receiving more intensive utilization by the U.S. Navy, and suggests that Navy projects have little measurable impact on the health of Pearl Harbor ecosystems.

760. Evans, R.J., J.D. Bails, and F.M. D'Itri. 1972. Mercury levels in muscle tissues of preserved museum fish. Environ. Sci. Technol. 6(10):901-905.

Flameless atomic absorption spectrophotometry was used to establish the total mercury levels in 57 preserved fish specimens of various species collected in the Lake St. Clair-Western Lake Erie region of the Great Lakes between the years of 1920-65. Only five fish were found to contain mercury levels in excess of 0.5 mg/kg--three large muskellunge collected in Lake St. Clair in 1939 (2.38, 1.57, and 1.58 mg/kg) and two adult sea lampreys collected in the Clinton River tributary to Lake St. Clair in 1938 (0.90 and 1.29 mg/kg). A trend was established relating the mercury content of selected categories of fishes with the year and location of collection for the fish specimens. The 1970-71 mercury levels in fish from the two study areas were higher than preserved museum specimens in the same categories taken from the same area.

761. Everhart, W.H., and R.A. Freeman. 1973. Effects of chemical variations in aquatic environments: Volume II, Toxic effects of aqueous aluminum to rainbow trout. U.S. Environ. Prot. Agen. Rept. EPA-R3-73-011B:1-41.

Fertilized eggs, fry and fingerlings were exposed to aqueous aluminum complexes in neutral and basic media under constantly flowing, controlled conditions of aluminum concentration, pH, and temperature. Toxicities of various concentrations were highly pH dependent. Dissolved concentrations over 1.5 mg/l aluminum caused physiological and behavioral aberrations as well as acute mortality. Toxic effects of suspended aluminum, though greater at lower concentrations, do not increase as much as the effects of dissolved aluminum with higher concentrations. Growth of trout exposed to high dosages of aluminum was reduced only as long as or slightly longer than the exposure continued. Egg and fry bioassays were conducted with exposures in trays and simulated natural nests. Fertilization was not affected by any concentrations tested, and most mortalities occurred during hatching and in the post-swim-up stage. Trends in toxicity were similar to those found with fingerlings indicating dissolved aluminum to be more toxic than equivalent suspended amounts.

762. Eyman, L.D. 1972. Cesium-137 and stable cesium in a hypereutrophic lake. Ph.D. Thesis: 1-113. Available from Univ. Microfilms, Inc., Ann Arbor, Mich. 48106, as 73-5367.

The inputs of Cs-137 and stable Cs and their distribution among the various components of an aquatic ecosystem were studied in a lake exhibiting an advanced stage of eutrophy. Components sampled and analyzed for these two isotopes of cesium included water, sediments, macrophytes, filamentous algae, zooplankton, and several species of fish. Most of the cesium pool (87% Cs-137; 98% Cs) was associated with the sediments. A trend of increased Cs-137 concentration at higher trophic levels was demonstrated for those fish that are free-ranging limnetic feeders. No such trend was evident for stable Cs. Forms closely associated with sediments had higher Cs-137 concentrations than expected based on their feeding habits. On the dates samples were collected, specific activity in limnetic fishes was constant but was variable in other forms. The degree of association of biotic forms with sediments was reflected in their specific activity.

763. Eyster, C., T.E. Brown, H.A. Tanner, and S.L. Hood. 1958. Manganese requirement with respect to growth, Hill reaction and photosynthesis. Plant Physiology 33(4):235-241.

Chlorella pyrenoidosa required a minimum of 10^{-7} mg/l manganese in the culture medium for heterotrophic growth and a 1000-fold larger amount for autotrophic growth. Autotrophic growth, Hill reaction, and photosynthesis responded equally when increments of manganese were added to manganese-deficient cultures. Similar results were obtained with *Scenedesmus quadricauda*, *Nostoc muscorum*, *Porphyridium cruentum*, and *Lemna minor*. The chlorophyll content of one-day-old autotrophic cultures of *Chlorella* and *Scenedesmus* was not affected adversely by manganese deficiency, but after being illuminated three days, manganese deficient cultures of *Chlorella* had much less chlorophyll than similarly treated non-deficient cultures. When manganese was added to deficient cultures, their capacities for photosynthesis and Hill reaction were quickly restored. *Chlorella* cultured in a medium containing manganese just sufficient for full photosynthesis and Hill reaction had a manganese-chlorophyll molar ratio of 1 to 600. The results indicate that a very small amount of manganese suffices as an essential enzymatic co-factor for heterotrophic growth, and that a much larger amount forms an essential part of the photosynthetic oxygen-evolving apparatus as previously suggested by others.

764. Faber, R.A., and J.J. Hickey. 1973. Eggshell thinning, chlorinated hydrocarbons, and mercury in inland aquatic bird eggs, 1969 and 1970. Pesticides Monitor. Jour. 7(1):27-36.

In the Upper Great Lakes States, 9 out of 13 species of fish-eating birds were found in 1969-70 to have sustained statistically significant decreases in eggshell thickness since 1946. Maximum changes in a thickness index occurred in great blue herons (-25%), redbreasted mergansers (-23%), common mergansers (-15%) and doublecrested cormorants (-15%). Heron eggs taken in Louisiana generally displayed a smaller post-'46 change than herons in the Middle West. On a lipid basis, mean PCB- and DDE-residue levels exceeded 100 ppm in 7 out of 13 species in the Great Lakes States, and in 2 of 7 species in Louisiana, the average DDE:PCB ratios in the two regions being 1.25:1 and 3.9:1, respectively. Individual dieldrin values tended to be higher in Louisiana (31.6 and 13.95 ppm in heron species from two different locations), although values reached 10.1 and 9.4 ppm in great blue and black-crowned night herons in Wisconsin. BHC averaged 3.01 and 0.39 ppm in the Lake States and Louisiana, respectively. Of eggs examined for mercury, 29% had levels greater than 0.5 ppm and 9% greater than 1.0 ppm on a wet-weight basis. Mercury levels in a small sample of eggs from Louisiana were consistently low. The differences in mercury levels between the two regions thus were similar to those found for the chlorinated hydrocarbons. While DDE was a prominent factor for most groups, especially herons, in relation to the eggshell thinning observed, dieldrin was also important to two groups even though DDE was present in much higher amounts. PCB's were also important to mergansers, while mercury was positively correlated with thickness index in grebes and negatively correlated in mergansers.

765. Fagerstrom, T., and B. Asell. 1973. Methyl mercury accumulation in an aquatic food chain. A model and some implications for research planning. Ambio 2(5):164-171.

This paper utilizes a mathematical model to study the mechanisms of methyl mercury (MM) accumulation in aquatic food chains. The three step food-chain model has pike (fish) feeding on roach (fish) and roach feeding on chironomids (insects). Functions in the model include environmental variables and equations describing some ecological and ethological processes that determine energy flow. Discussion is limited to 3 specific problems. (1) Can the model mimic, in a qualitative sense, the static picture common in nature, i.e. MM concentrations in fish increasing with age, and concentrations in predatory species exceeding those in prey species by a factor of 2 to 5? (2) What is the relative importance of the accuracy of the numerical values for the calculated MM concentrations in the fish? (3) What are the dynamics of the reaction of the system to perturbations in the same simulations as were used for the sensitivity analysis?

766. Fagerstrom, T., B. Asell, and A. Jernelov. 1974. Model for accumulation of methyl mercury in northern pike, Esox lucius. Oikos 25:14-20.

A compartmental model of mercury residue accumulation in individual fishes is presented. The model assumes a single residue pool that acquires methyl mercury from respired water and with the diet. Uptake and clearance of residue are treated as functions of metabolic rate, which is itself size-dependent. The parameters for the model are estimated from a release-recapture experiment and from literature data, and the solutions produced by the model when using these estimates are compared with real-world data where the latter set of data is independent of the set that was used for parameter estimation. The correspondence between the calculated concentration of methyl mercury in lateral muscle tissue and empirically observed values is acceptable though the calculated values in the lower weight range are somewhat high. The possibility that the model may apply to other substances is discussed.

767. Fagerstrom, T., and A. Jernelov. 1972. Some aspects of the quantitative ecology of mercury. Water Research 6(10):1193-1202.

The principal ways of transformation of mercury in aquatic ecosystems are discussed. The mercury transformations include: (1) formation of HgS, (2) conversion of HgS, (3) formation and oxidation of elementary Hg, (4) formation of complexes between divalent mercury and organic substances and the release of Hg therefrom, (5) formation of mercury-inorganic material complexes of the silica- and ferro-manganese-type, (6) release of soluble mercury from complexes, and (7) formation and degradation of methylmercury and dimethyl-mercury. The quantitative influences on these processes of some physico-chemical and biological factors are demonstrated from field investigations and laboratory experiments. A dynamic model for the transport of methylmercury in a simplified limnic food-chain (including fish, mollusca, and crustacea) is outlined.

768. Fang, S.C. 1973. Uptake and biotransformation of phenylmercuric acetate by aquatic organisms. Arch. Environ. Contam. Toxicol. 1(1):18-26.

Guppy, snail, elodea, and coontail, when exposed to water containing Hg-203-labeled phenylmercuric acetate (PMA), readily take up PMA and the PMA uptake is related to the time of exposure and the PMA concentration, the absorbed PMA being mainly converted to inorganic mercury. Ethylmercuric chloride is a minor metabolic product. Mercury-203 is not quickly eliminated from the guppy, elodea, and coontail when they are placed in fresh water, the biological half-life of Hg-203 residues ranging between 43 to 58 days.

769. Felton, B.H.D. 1972. The relationship between ions and ciliary activity in the gill of Mytilus edulis. Ph.D. Thesis. Available from University Microfilms, 300 N. Zeeb Rd., Ann Arbor, Mich. 48106, as 73-1475.

The relationship between major ions in artificial sea water (ASW) of normal balance and beating of lateral cilia and other types of cilia in excised gill of mussel, Mytilus edulis, was investigated. ASW was used to perfuse a ganglion-nerve gill preparation. Rate of ciliary beating was determined by timing metachronal waves with a stroboscope. The effect of Na, K, Ca, Mg, and Cl, on basal beat frequency and on cilioexcitatory effect of 5-hydroxytrptamine (5-HT), KCL, and caffeine was determined. Li, Ba, Mn were studied for the same effects. By replacing ions in ASW of normal balance with substitutes, such as other ions, choline, gluconate salts, or sorbitol, it was possible to detect the influence of major ions. Tetrodotoxin (TTX) 0.000016 M does not inhibit ciliary activity of gill in ASW. In a 1:1 choline/Na ASW, TTX 3 microM (1 microgram/ml) inhibits lateral cilia and blocks the cilioexcitatory effect of KCL. Li at 42 mM is also inhibitory and blocks excitation by 5-HT. Nerve stimulation with electrical current is partially blocked by Li. The addition of 5-HT to gills in ASW causes a rapid efflux of Ca from gill tissue followed by an influx of Ca. When Mn was substituted for Ca in the presence of TTX in 1:1 choline/Na ASW, cilioexcitation by 5-HT and caffeine were not blocked. When Ba or Mn is substituted for Ca in ASW, the basal beat frequency is elevated. The effect of excess ions on basal beat frequency and on cilioexcitatory effect of 5-HT was also studied. 5-HT, a known cilioexcitatory agent and metabolic activator in Mytilus gill, has now been shown to cause a change in the membrane permeability of gill tissue to Ca. 5-HT causes a rapid efflux followed by an influx of Ca from internal stores of the ion in gill tissue. This indicates that the chain of events initiated by 5-HT in gill tissue of Mytilus edulis involves Ca release, increased glycolysis, and the formation of ATP which results in cilioexcitation.

770. Ferrell, R.E., T.E. Carville, and J.D. Martinez. 1973. Trace metals in oyster shells. Environmental Letters 4(4):311-316.

Measurements using atomic absorption spectrometry established the presence of Pb, Hg, Cd, Zn, Cu, and Cr in shells of oyster Crassostrea virginica in amounts considerably higher than concentrations in seawater. Preliminary comparisons of trace elements in shells from widely separated areas do not suggest large differences. The relatively high values obtained for Pb, Cu, and Cd suggest these analyses have a good potential for assessment of man's contribution to global pollution. Comparison of these data with trace element content of ancient shells may be useful in evaluating the importance of pollution induced changes in coastal waters.

771. Fimreite, N. 1970. Mercury uses in Canada and their possible hazards as sources of mercury contamination. Environmental Pollution 1(2):119-131.

During the past ten years mercury consumption has shown a strong upward trend in Canada. The major proportion of this increase can be accounted for by the chloralkali industry, from which nearly 100,000 kg of mercury are released into the environment each year. Most of this mercury finds its way to watercourses exposing aquatic ecosystems where mercury is known to accumulate. The use of mercury compounds for slime control in the Canadian pulp industry is decreasing, but in one case elevated mercury levels in fish were traced back to such a source. Also decreasing is the use of seed-dressings containing mercury, although this use of mercurials is still considerable, and in view of findings in other countries elevated mercury levels in seed-eating birds and their predators must be expected. Elevated levels of mercury were found in pheasants and partridges collected in Southern Alberta where mercury seed-dressings are extensively used.

771A. Fimreite, N. 1974. Mercury contamination of aquatic birds in Northwestern Ontario. Jour. Wild. Manag. 38(1):120-131.

A total of 184 specimens of fish-eating and aquatic birds were collected on or near five different lakes in northwestern Ontario and analyzed for total mercury in liver. Mercury concentrations were highest in specimens collected about 75 and 120 km downstream from where a chlorine plant is believed to be the source of contamination. The concentrations reached or approached 100 mg/kg in some scavengers and fisheaters like turkey vulture (*Cathartes aura*), common merganser (*Mergus merganser*), raven (*Corvus corax*), and common loon (*Gavia immer*), while concentrations in typical surface feeding ducks, mallards (*Anas platyrhyncos*) and pintails (*A. acuta*) were generally below 10 mg/kg. The liver concentrations in specimens from three lakes receiving no effluent from the plant averaged only 10% of those reported above, but the same relationship between trophic feeding levels and mercury concentrations was shown. Additional analyses of breast muscle tissue of 97 specimens revealed an average concentration of 32% of that in liver with no significant variation with contamination level of birds. Correlation between concentrations in liver and breast muscle was generally very good. The methyl mercury concentrations in 51 specimens of ducks averaged 36% of total mercury in liver and 60% in breast muscle tissue. No interspecific differences were found for muscle concentrations of methyl mercury while in liver common merganser carried only 12% of the mercury in this form versus 32, 38, and 52% for common goldeneye, mallard, and pintail respectively. In the stomach contents of 12 specimens representing four species, the methyl fraction comprised 58% of total mercury with little interspecific variation. A survey of the study area, in which the number of young in broods of aquatic birds were counted, revealed that young of loons were completely absent in both lakes including the reach linking these lakes. Two tern colonies were compared with respect to reproductive success. The first one apparently reproduced normally while the fledging success in the latter was about 10% only. Average total mercury levels in egg samples were 1.00 and 3.65 mg/kg respectively and the corresponding values for methyl mercury 0.82 and 2.40 mg/kg.

772. Fimreite, N., W.N. Holsworth, J.A. Keith, P.A. Pearce, and I.M. Gruchy. 1971. Mercury in fish and fish-eating birds near

sites of industrial contamination in Canada. Canadian Field Naturalist 85:211-220.

Concentrations of mercury were determined in fish muscle, livers and eggs of fish-eating birds, and bivalve molluscs. Most of the material was collected near sites of industrial contamination: a mercury mine, chloralkali plants and pulp mills known to use or have used mercury. Most sites showed substantial mercury contamination, especially downstream from the above sources. Mercury levels exceeding 0.5 mg/kg were found in practically all samples of freshwater fish. Individual walleye (Lake St. Clair), pumpkinseed (St. Clair River), and lake trout (Pinchi Lake) contained concentrations up to 5.01, 7.09, and 10.50 mg/kg of mercury respectively. Lower levels were found in marine fishes from coastal waters. A positive correlation was found between body weight and mercury concentration in most fish samples, and also between the trophic feeding level and mercury concentration in both fish and fish-eating birds. The highest mercury level in the livers of fish-eating birds was 17.40 mg/kg (Red-necked grebe). Four Common Tern eggs averaged 0.58 mg/kg and two Red-breasted Merganser eggs averaged 0.81 mg/kg. The mercury concentrations are discussed in terms of published data on hazard to human health and to reproduction in fish-eating birds.

773. Fimreite, N., and L.M. Reynolds. 1973. Mercury contamination of fish in Northwestern Ontario. Jour. Wild. Manag. 37:62-68.

Mercury levels were determined in lateral musculature of fish from Northwestern Ontario in specimens taken upstream and downstream from a chlorine plant, and from a number of lakes not contaminated from any known source. The maximum mercury levels in northern pike (Esox lucius), burbot (Lota lota), and walleye (Stizostedion vitreum) were 27.8, 24.8, and 19.6 mg/kg respectively, measured in specimens taken 75-100 km downstream from the plant. Levels decreased proportionally to the distance from the plant but were clearly elevated even 300 km downstream. The levels in specimens from suspected uncontaminated lakes were generally below 1 mg/kg but frequently above the 0.2 mg/kg often considered as the maximum background concentrations. The latter finding may possibly be explained on the basis of the oligotrophic conditions characteristic for these lakes.

774. Finch, R. 1973. Effects of regulatory guidelines on the intake of mercury from fish--the MECCA project. U.S. Dept. Comm., Fish. Bull. 71(3):615-626.

The MECCA (Model for the Estimation of the Consumption of Contaminants from Aquatic Foods) program applies a survey of the fish consumption habits of a sample of over 4,500 individuals, representative of the U.S. population, to build a computer model which uses known levels of microconstituents in 52 kinds of fish to predict the distribution of the daily intakes of the microconstituents from fish among the survey participants. The model was applied to Hg levels in fish to estimate effects of guidelines (maximum permitted levels) for fish in protecting the population against excessive intake. For the sample population, intakes of Hg from fish would remain safe if the guideline for Hg in fish were raised from the present level of 0.5 mg Hg/kg wet to 1.5 mg Hg/kg wet. The effect of such an increase would be of benefit to both the consumer and the fishing industry. This model can be used to predict the distribution of consumer intakes from fish of any constituent present in fish, whether nutritious or potentially hazardous, for which levels in the edible portion of 52 kinds of fish used in the model are known.

775. Finkel, A.J., and W.C. Allee. 1970. The effect of traces of tin on the rate of growth of goldfish. Amer. Jour. Physiol. 130:665-670.

Tin, as stannous ion, in concentrations of the order of 0.000005 M (0.295 mg/l), has been found to accelerate growth of goldfish, during brief assay periods, over that of untreated control fish. This report extends, for the first time, the stimulating properties of traces of tin to the growth of vertebrate organisms.

776. Fitzgerald, B.W., and D.M. Skauen. 1963. Zinc-65 in oysters in Fishers Island Sound and its estuaries. In Schultz, V., and A.W. Klement, Jr. (eds.). Radioecology, Reinhold Publ. Corp., New York: 159-162.

Zinc and zinc-65 in American oysters from Fishers Island Sound and its estuaries was determined. Zinc content of oysters from a given locale varies considerably, also background levels of zinc-65 are not static. The year-long study showed a peak value from February to May of 1961 and a sharp increase during the month of June and continuing. These results were observed during the same season the previous year. Rate and extent of zinc-65 uptake by oysters was observed in the laboratory. A variety of zinc-65 salts was administered and effect of the various anions noted. In one instance, zinc-65 was complexed with a commercially available complexing agent. The addition of zinc-65 labeled salts to oysters grown in sea water demonstrated that much zinc-65 became associated with shells and that a limit to the amount of zinc-65 taken up occurred in the first 24 hours. Complexation of the radioactive ion had a considerable effect on the rate and extent of zinc-65 uptake by the tissue. Of equal importance was the observation that complexation of the ion virtually eliminates all association between the ion and shells.

777. Fitzgerald, G.P. 1966. Use of potassium permanganate for control of problem algae. Jour. Amer. Water Works Assoc. 58(5): 609-614.

Author treated various species of algae with different concentrations of potassium permanganate and copper sulfate in order to determine concentrations required to kill cells after 12 and 72 hours treatment and to prevent growth of various species of cyanophytes, chlorophytes and diatoms. Toxicity of copper sulfate was highly variable; cyanophytes except Oscillatoria were killed at concentrations of 0.1 mg/l; others were killed after 4 hours at 0.4 mg/l; growth of these species was inhibited by 0.1-0.2 mg/l of Cu. With potassium permanganate, almost all species were killed by 1-5 mg/l. Author speculates that variations in effectiveness of copper may result from variations in metabolic rates, metabolic processes, or rates of absorption among the several species, and suggests that potassium permanganate treatment of raw-water reservoirs may be utilized effective by an algicide and subsequent elimination of tastes and odors resulting from decomposed algae.

778. Fitzgerald, G.P. 1967. The algistatic properties of silver. Water, Sew. Wks. 114:185-189.

Growth inhibition of 4 species of freshwater algae in 10 days was effected by 7-24 mg/l of the silver products tested (as low as 0.02 mg/l Ag^{2+}); on an equal silver basis, inorganic salts were more effective than organic salts. Increasing algal cell density by a factor of 3 also affected the concentrations of test products necessary to produce growth inhibition by about a factor of 3. Chlorella can detoxify concentrations of silver 16 x more than those concentrations required for algistatic activity. On the bases of these and other data, author concludes that silver compounds can effectively control algae in swimming pools provided that little or no bromine or iodide are present.

779. Fitzgerald, G.P., and M.E. Der Vartanian. 1965. Pseudomonas aeruginosa for the evaluation of swimming pool chlorination and algicides. Appl. Microbiol. 17(3):415-421.

Concentrations of ammonia and the chlorine stabilizer, cyanuric acid, which could be expected in swimming pools decreased the rate of kill by chlorine of the potential pathogen, Pseudomonas *aeruginosa*. The effect of cyanuric acid increased as the concentration of chlorine decreased, a fact of significance from a public health view. Quaternary ammonium algicides had little effect on the kill rate of chlorine, but an organic mercury algicide had a synergistic effect with chlorine when the chlorine activity was stressed by the addition of ammonia or the use of 100 times the normal concentration of bacteria. The effect of natural waters, rain, beaches, and swimming pools on the kill rate by 0.5 mg of chlorine per liter indicated that a treatment time of 1 hr or more was required to kill 99.9% of 10^6 *Pseudomonas* cells per ml. The synergism of chlorine and the organic mercury algicide was also demonstrated with these waters and with sewage treatment plant effluents.

780. Fitzgerald, G.P., and S.L. Faust. 1965. Effect of bacteria on the solubility of copper algicides. Water Sew. Wks., July, 1965; Univ. Wisconsin Eng. Exp. Sta. Rep. 796:5pp.

Experiments were conducted with different sources of copper reported to be useful in preventing precipitation of copper from hard waters. Data indicate that after one to five days the proportion of copper soluble in solutions in medium-hard, and very-hard, waters decreased from levels of 53 to 96% soluble to less than 10% soluble. This loss in solubility of copper was due to bacterial degradation of chelating agents protecting solubility of copper, as shown by tests with solutions of copper sources protected from the action of bacteria by addition of algicide, Algimycin-200, or by autoclaving solutions and maintaining them under sterile conditions.

781. Fogg, G.E., and D.F. Westlake. 1953. The importance of extracellular products of algae in freshwater. Verh. Int. Verein Theor. Angew Limnol. 12:219-232.

Experiments with partially purified preparations of extracellular polypeptide, produced during normal growth of the blue-green alga, *Anabaena cylindrica*, show that this material forms complexes with various ions including those of copper, zinc, ferric iron, phosphate and certain organic substances. Complex ion formation may have biologically important effects, and, as an example, authors suggest that complex formation between extracellular polypeptide and cupric ion considerably reduces toxicity of the latter toward *Anabaena cylindrica*. This may explain the erratic results often obtained with copper sulphate used as an algicide. Algae representing other classes (*Chlorophyceae*, *Xanthophyceae*, *Balcillariophyceae*) also produce extracellular peptides. That relatively substantial amounts of peptide-nitrogen occur dissolved in lake waters has been confirmed for a number of English lakes and reservoirs. It is suggested that this peptide may originate partially from living algae and that by forming complexes with other dissolved substances, it may exert important effects on growth of aquatic organisms. Specific substances may not be necessary, and in lakes, complex-forming substances derived from organic decay or living algae, may effectively produce the requisite environment for cyanophytes.

782. Folsom, T.R., and T.M. Beasley. 1973. Contributions from the alpha emitter, polonium-210, to the natural radiation environment of the marine organisms. In Radioactive Contamination of the Marine Environment, Int. Atom. Ener. Agen., Vienna, Austria: 625-632.

There is evidence that many marine organisms accumulate natural alpha emitters to levels that might be contributing substantially to their burden from ionizing radiation. There are increasing opportunities for alpha emitters to enter the ocean because of the increasing use of plutonium-239. Distributions of polonium-210 are of interest because this natural nuclide accumulates to relatively high levels in some of the same marine ecosystems that accumulate plutonium effectively. The progress of the natural nuclide is technically much easier to follow, yet its distributions might serve to give some warning as to the probable fate of plutonium. Concentrations of polonium-210 in a variety of marine organisms, especially crustaceans, are compared and also the radioactive burdens that may be inferred from bulk tissue samples. Some difficulties of interpretations are discussed and the need for more detailed measurements in specific organs and tissues. Some inferences about polonium-210 from lead-210 measurements are also presented.

783. Folsom, T.R., R. Grismore, and D.R. Young. 1970. Long-lived γ-ray emitting nuclide silver-108m found in Pacific marine organisms and used for dating. Nature 227:941-943.

Tissues from several species of marine organisms, including squid, tuna, and lobster, collected in 1964 from widely separated regions of the North Pacific contained ^{108m}Ag, a γ-ray emitting man-made nuclide with a half-life reported to be greater than 100 yr.

An initial ^{110m}Ag/^{108m}Ag activity ratio of 162 was assumed in the dating computations, this being the value reported immediately after activation of natural silver in a reactor experiment. The salient feature of ^{108m}Ag is that it is an artificial γ-ray emitter with an exceptionally long life, longer than any other man-made γ-ray emitter reported anywhere in the biosphere. Both these nuclides seem to be activated together when ordinary silver is exposed in reactors and in the detonation of certain weapons.

An idea of the use of $^{110m}Ag/^{108m}Ag$ dating can be gained by considering how the animals could have come into contact with the observed silver nuclides. This requires reference to reported dates when specific large weapons were tested; to the reported character of the global fallouts that followed; and to the motion and stratification of upper layers in the Pacific. The testing of very large nuclear weapons was renewed abruptly on October 23, 1961; other tests were made in 1962, especially in the autumn. The observed silver nuclide ratios indicate the absence of large amounts originating in 1958 and earlier. Thus the observed silver nuclides most likely originated within the 1961 and 1962 testing periods.

After the 1961-62 weapons tests, there were intense global fallouts during the spring of 1962, 1963, 1964, especially intense at latitude 40°-50° N. Presumably the observed ^{108m}Ag could have entered the sea any time after October 23, 1961, but the largest fraction of silver of 1961 origin should have entered in the spring of 1962. Lesser amounts that had been stored in the stratospheric reservoir should then have followed late in 1962, and also in 1963 and 1964. But, after the summer of 1962, and especially after October 1963, all the 1961 fallout must have been mixed with some that originated in 1962. This mixture would be expected to have entered the ocean most rapidly in the spring of 1963, yet some with slightly different silver nuclide mixtures should have fallen later, especially in the spring of 1964.

Finding mixtures of silver nuclide ratios in organisms corresponding closely to late origin therefore indicates that either very little radioactive silver was formed in 1961 compared with 1962, or the species with the late origins lived in regions where silver was dispersed or depleted rapidly, and they adjusted rapidly to changes in silver in their environment. The first alternative is unlikely because of findings in the case of the albacore.

All but one of the species inspected had large fractions of 1962 fallout as indicated by the radiosilver ratios. One squid contained a nuclide ratio that might have come from the autumn of 1962 when the final large tests of this post-moratorium series took place. This squid was feeding at the surface when captured. It seems therefore that its feeding region was being rapidly depleted of silver (and perhaps of other trace metals), and also that the biological half-life of the species was short--of the order of a few weeks or months.

Another squid, some tropical tuna, and some lobsters from a small island also contained silver nuclide ratios that suggest associations with water masses which were constantly depleted of silver, again suggesting rapid turnover of silver traces in the organisms or in their food. The lobsters of Guadalupe usually live in shallow layers, and presumably, from the silver nuclide ratio found, they depend on food with similar environment. Yellowfin tuna are caught at the surface; the silver ratios they contain suggest that their food comes from regions where there is a rapid turnover of silver. Mussels collected from tide pools in a calcareous apron of Okinawa where rain containing relatively high concentrations of fallout struck the organisms directly during periods of low tide, could have resulted in accumulation and retention in their fixed substrate and in other sessile organisms living nearby. In addition to recent fallout, therefore, early fallout rich in 1961 silver nuclides could well have remained available to the mussels until 1964 when they were collected. Their nuclide ratio of intermediate value suggests this possibility.

A mechanism can be suggested to explain how a trace element might be isolated and kept pure quite effectively for several years in thin subsurface layers while moving thousands of miles, and thus how albacore could have encountered essentially pure 1961 radioactive silver.

No evidence of hazard to humans should be inferred from the finding of long-lived ^{108m}Ag in commercially collected tuna. The activities measured were at or near naturally occurring levels of radioactivity in tissues.

784. Folsom, T.R., and D.R. Young. 1965. Silver-110m and cobalt-60 in oceanic and coastal organisms. Nature 206(4986):803-806.

Another nuclide, one scarcely mentioned as a weapon detritus, was found to be spread widely in the ocean and often concentrated more highly than Co-60 in digestive tissues of molluscs and crustaceans. This is Ag-110m, having a half-life of 253 days. Little is known of concentration levels or chemical forms taken by either of these nuclides in sea-water of the open ocean; nevertheless, their presence is made known through examination of remarkable accumulations built up by living organisms.

Early inspections indicated that Co-60 frequently accumulates most effectively in liver or analogous digestive gland tissues of lower animals. It has not been convenient to dissect this tissue routinely in mussels and barnacles, but this has been done on larger squid and fish. In oceanic squid, *Stenoteuthis bartrami*, for example, about 90% of the Co-60 activity was found in digestive gland, which contributes less than 5% to the total body weight.

The distribution of Ag-110m is not identical with that of Co-60. Highest concentrations of both nuclides were found in livers of squid from the northeast Pacific; the same species of squid from

Hokkaido containing Ag-110m exhibited no significant Co-60, and this discrepancy also was observed in other squid from California, Hawaii and the Grand Banks.

A contrast can be seen in concentrations of Co-60 (and also Ag-110m) in two Pacific albacore populations. These fish are exploited by large commercial fisheries and some of their habits are known. The southern fish apparently live much of their life in low latitudes, where fallout rate is relatively low. The northern population is believed to traverse the northern Pacific annually along higher latitudes where highest fallout accumulations have been reported. Many individuals have been observed to pass through the areas where highest concentrations of Co-60 and Ag-110m were observed in squid in 1964. Albacore are known to eat large amounts of squid, and it is not surprising therefore that higher Co-60 concentrations were observed in the northern population than the southern. Of course, albacore may obtain Co-60 from small fish and crustaceans also, but these, too, are influenced by local fallout.

785. Folsom, T.R., D.R. Young, J.N. Johnson, and K.C. Pillai. 1963. Manganese-54 and zinc-65 in coastal organisms of California. Nature 200(4904):327-329.

It is estimated that 8-55 curies of zinc-65 enter the Pacific each day at the mouth of the Columbia River along with other nuclides arising from activation of cooling water constituents at Hanford.

However, zinc-65 in water from the open coast at La Jolla some 2500 km south of the Columbia River is now so dilute that some samples have failed to produce reliable measurements of this nuclide. Local coastal organisms representing several phyla have been able to concentrate zinc-65 so effectively that its presence is easy to measure with little or no chemical treatment. From gamma-spectra made during these studies, it became apparent that another nuclide, manganese-54, was accumulating in many marine organisms and in concentrations somewhat higher than zinc-65.

Organisms analyzed were all from open coastal waters beyond obvious influence of harbors or rivers. Deep-living scavengers represented by the local hagfish and also an amphipod were taken in traps set at 200-400 m. Barnacles and mussels and fish have been collected for comparison from widely scattered coastal points, but only those taken near southern California are listed. Some sessile algae are listed, and these show the wide divergence that is common in comparisons of like species.

It appears that certain dinoflagellates, and other organisms from the same coastal waters, can concentrate manganese-54 several thousand fold. Mussels and barnacles appear to concentrate manganese-54 more than zinc-65, whereas fish do the opposite. Surface fish contain distinctly more of both metals than do the deep-living hagfish; the second scavenger is an amphipod and ratio and concentrations are again different.

The concentration for zinc-65 in the environmental water was not established; nevertheless, it was suggested that the concentration of zinc-65 must be no more than about 10% of what was observed in seawater for manganese-54. From this, and measurements in the organisms, authors conclude that some surface fish can concentrate zinc-65 by three orders of magnitude. It is of interest to compare the average concentration (33 μμc./1) of zinc-65 in Mytilus from La Jolla with that found in specimens from the Oregon coast about 150 kms from the mouth of the Columbia River; the latter was 6,750 μμc./wet kg.

786. Forrester, C.R., K.S. Ketchen, and C.C. Wong. 1972. Mercury content of spiny dogfish (Squalus acanthias) in the Strait of Georgia, British Columbia. Jour. Fish. Res. Bd. Canada 29:1487-1490.

Total mercury content of Squalus acanthias sampled in the Strait of Georgia reached levels of 0.5 mg/kg at fish lengths of 72 and 77 cm for male and female fish, respectively. For any given length above 65 cm the mercury content was higher among males than females and higher in samples taken off the Fraser River Estuary than in other areas of the Strait. Levels of mercury reached 1.7 mg/kg in males (to 95 cm in total length) and almost 2.0 mg/kg in females (to 120 cm in total length).

787. Förstner, U., and G. Müller. 1973. Heavy metal accumulation in river sediments: A response to environmental pollution. Geoforum 14:53-61.

Eight heavy metals from the clay fraction of sediments from major rivers within the Federal Republic of Germany were determined by atomic absorption. Heavy metals especially known for their high toxicity are enriched most: mercury, lead and zinc by a factor of 10; cadmium by a factor of 50, as compared with the natural background of these elements. A mobilization of heavy metals from the suspended load and from the sediments, as to be observed in rivers approaching the marine environment, could endanger marine organisms, thus negatively influencing the aquatic food chain. With a further increase of heavy metal pollution, a threat to the drinking water supplied by rivers and lakes cannot be excluded.

788. Foster, R.F. 1963. Environmental behavior of chromium and neptunium. In Schultz, V., and A.W. Klement, Jr. (eds). Radioecology. Reinhold Publ. Corp., New York: 569-576.

The most abundant source of chromium is chromite ore with the largest known domestic reserves situated in Montana. Chromium has been detected in living organisms in only trace quantities and seemingly plays no essential role in the physiology of plants or animals. The principal means through which chromium enters the biosphere is the liquid and gaseous effluents of industrial plants which use this element. Chromium is a toxic material and if present in high concentration can damage plants, animals, and humans. Aquatic organisms appear to be especially vulnerable. The hexavalent state is more readily assimilated than the trivalent state and is generally considered to be at least a hundred times more toxic than the trivalent state. The red blood cells have a strong affinity for hexavalent chromium which has led to the popular use of radiochromium (chromium-51) in clinical studies of hematologic disorders. Ultimately, chromium is concentrated in the reticuloendothelial system, and in humans it is eliminated principally in the urine. Chromium-51 is the only radioisotope which has environmental importance at the present time, and this isotope is present in the effluent from the Hanford reactors which enters the Columbia River. Retention by Columbia River solids is measurable but not of great significance. Chromium-51 accumulates in algae of the river, but its concentration diminishes rapidly in higher trophic levels. The exposed parts of crops which have been in direct contact with irrigation water which contains chromium-51 may have detectable quantities of this isotope, but root crops and fruits contain insignificant amounts. It has not been found in milk or other products of animals grazed on irrigated pasture. Chromium-51 has little radiological significance since its decay to stable vanadium releases very little ionizing radiation.

The artificial element neptunium has two radioisotopes of some interest to ecologists. Neptunium-239 is created by the capture of a slow neutron by uranium-238 and decays with a half-life of 2.3 days to become fissionable plutonium-239. Substantial quantities of neptunium-239 are created in plutonium-producing reactors and in conventional atomic bombs, and thus it has been measured in the environment. The alpha-emitting isotope, neptunium-237, has not entered the biosphere in appreciable quantity. It has a very long half-life (2.2 x 10^6 years) and thus a very low specific activity. The element, which resembles the rare earths in several aspects, is not easily incorporated into ecosystems, and it has not been reported in terrestrial biota or beyond the second trophic level in aquatic forms. The radiological importance of neptunium has primarily been associated with the presence of neptunium-239 in drinking water and the potential dose imparted to gastrointestinal tract.

789. Fowler, S.W., and G. Benayoun. 1974. Experimental studies on cadmium flux through marine biota. In Comparative Studies of Food and Environmental Contamination, Inter. Atom. Ener. Agen., Vienna, Austria: 159-178.

The role of mussels (Mytilus galloprovincialis) and benthic shrimp (Lysmata seticaudata) in the cycling of cadmium in the marine environment was examined. Results from Cd-109 uptake experiments indicated that steady state between water and the organisms was not reached after 2 months. Concentration factors computed at this time were 130 and 600 in whole mussels and shrimp, respectively. Concentration factors based on stable cadmium concentrations were several times higher, indicating imcomplete equilibration between Cd-109 and stable cadmium in the organisms. Mussels had the highest Cd-109 concentrations in viscera with lesser amounts in muscle, mantle, gills, and shell, respectively. The highest Cd-109 concentration in shrimp was also found in viscera, followed by exoskeleton, muscle and eyes. Relative differences between stable and radiocadmium content of certain tissues are discussed. Increased cadmium uptake at higher temperatures was noted in shrimp, whereas uptake by mussels was unaffected by temperature. The uptake of cadmium was directly proportional to cadmium content in seawater; however, accumulation was unaffected by varying the zinc concentration. Shrimp tended to lose cadmium faster at higher temperatures; however, differences were not significant over the 2 months loss period. Shrimp maintained in a flowing seawater system retained an average 55% of their original Cd-109 body burden after 8 months. The biological half-life, computed over a 7 month period, was 378 days. The relatively slow loss of Cd-109 from mussels was not affected by either the levels of zinc in their tissues or zinc concentration in the surrounding seawater. Mussels maintained at a field station lost significantly less Cd-109 than a similar group held in the laboratory flowing seawater system during the first 3 months. After this time field animals fluxed cadmium 4 times faster (Tb1/2 = 307 d) than the laboratory group (Tb1/2 = 1254 d). The observed discrepancy between flux rates is thought to be related to differences in organisms' food supply. It is concluded that cadmium flux is a relatively slow process in mussels and shrimp. Animals coming into contact with cadmium polluted waters will retain a significant fraction of the accumulated metal for a relatively long period of time.

790. Fowler, S.W., M. Heyraud, L.F. Small, and G. Benayoun. 1973. Flux of 141 Ce through a euphausiid crustacean. Marine Biology 21:317-325.

The role of the Mediterranean euphausiid Meganyctiphanes norvegica in the cycling of radiocerium (Ce-141) was examined. When uptake of Ce-141 occurs directly from the water, a "dynamic" population equilibrium is reached at a concentration factor of about 250. Molting was responsible for up to 99% loss of total body burden at first molt, and about 45% of the remaining activity at second molt, thus denying true long-term equilibrium to individual animals. Fecal pellets did not contain measurable Ce-141 activity when the euphausiids accumulated the isotope from water, thus proving that surface adsorption was the key accumulating process from water. When radiocerium was taken in through ingestion of labelled Artemia, about 99% of the body burden was voided as fecal pellets. Excretion by this route was accelerated when euphausiids were fed non-radioactive Artemia during loss phase. Radioactive counts of pellets confirmed that all ingested Ce-141 was lost through defecation. When Ce-141 was ingested as labelled phytoplankton, a substantial fraction of total body burden occurred in the molts, which indicated that phytoplankton lost Ce-141 to water and the radioactivity was subsequently adsorbed to outer surfaces of the euphausiids. Molts, fecal pellets, and freshly-killed euphausiids lost Ce-141 to water exponentially, rates being similar to the exponential portions of loss curves for live, non-molting individuals. It is suggested that M. norvegica, and probably other pelagic zooplankters, can greatly accelerate radiocerium transport to the ocean floor by packaging the isotope as fecal pellets. In coastal areas subject to low-level radioactive waste disposal, Ce-141 might be ionic (or at least soluble) to a great extent, in which case euphausiids could take up the isotope rapidly and accelerate its vertical transport via molting.

791. Fowler, S.W., L.F. Small, and J.M. Dean. 1971. Experimental studies on elimination of zinc-65, cesium-137 and cerium-144 by euphausiids. Marine Biology 8:224-231.

The elimination of 3 radionuclides from Euphausia pacifica was measured over a 5 month period. The biological half-lives for Zn-65, Cs-137, and Ce-144, calculated after the euphausiids had ingested radioactive Artemia nauplii, were found to be 140 days, 6 days, and 7.5 h, respectively. the percentages of body burdens lost in molts were greatest for the fission products, Ce-144 (21%) and Cs-137 (7%), and least for Zn-65 (1%). Elimination of the isotopes in the feces could not be followed because of the difficulty in collecting fecal material for analysis; however, 1 sample collected 2 months after the beginning of the elimination experiment had no measurable radioactivity. Loss of Zn-65 from molts and time to disintegration of the molts were found to be temperature dependent over a 5° to 15°C range, and the sinking rate of molts was both temperature and salinity dependent. Calculations showed that, in areas in the North Pacific outside the influence of upwelling, percentage of Zn-65 loss from sinking molts (before disintegration of the molts) was likely to be the same throughout the year, since the molts would be exposed to about the same mean temperature in the water column in all seasons. Even though temperature structure in the upper layers changes with season, mean temperatures change very little when calculated over the sinking distance of intact molts. Intact molts would sink to slightly over 400 m in the absence of turbulence, and would lose 87% of their Zn-65 by the time they reached this depth. Sinking molts thus might contribute substantially to the vertical transport of Zn-65 in the sea. If loss of Zn-65 in fecal pellets is assumed to be small under our experimental conditions, and molting loss is only 1% of Zn-65 body burden, the major mechanism of Zn-65 loss from euphausiids feeding on non-radioactive food must be isotopic exchange with the water. Approximately 96% of the initial body burden was eliminated over a period of 5 months.

792. Foy, C.D., and G.C. Gerloff. 1972. Response of Chlorella pyrenoidosa to aluminum and low pH. Jour. Phycology 8(3): 268-271.

Chlorella pyrenoidosa, a green alga which has no measurable Ca requirement, tolerated much higher Al concentrations in solution than higher plants which require considerable Ca. This alga also gave significant positive yield responses to Al concentrations between 1.5 and 12 mg/l (added at pH 4.6). The positive Al response was not attributable to V, Cr, Ni, Co, W, or Ti contaminants in the Al salt. A strain of C. pyrenoidosa having even greater Al tolerance was isolated by subjecting the original Strain I (Fitzgerald) culture to increasing Al stress. This strain, I-Al, grew in stagnant cultures containing 48 mg/l Al at an initial pH of 4.2. Its yield also was not significantly decreased by 48 mg/l Al in aerated cultures when both inoculum and solution pH were 4.6. Under the same conditions the original Strain I organism was injured by 3 and 6 mg/l Al and was killed by 12 mg/l. Algal strains which differ in Al tolerance may be useful (1) in studies on the mechanism of Al toxicity and mineral nutrition in general; and (2) in raising the pH, precipitating Al, and thereby detoxifying Al-containing acid mine drainage water and commercial wastes.

793. Fraizier, A., and A. Vilquin. 1971. An experimental study of ^{137}Cs elimination in the mullet Mugil chelo and the blenny Blennius pholis. Marine Biology 10:154-156.

Study of the decontamination of two marine fishes contaminated by Cs-137 reveals two distinct elimination stages: one fast, the other slow. The corresponding biological half-lives have been determined: for the fast stage it ranges from 20 to 30 days for both species; for the slow stage it is 154 days for mullet and 203 days for blenny.

794. Freeman, H.C., D.A. Horne, B. McTague, and M. McMenemy. 1974. Mercury in some Canadian Atlantic coast fish and shellfish. Jour. Fish. Res. Bd. Canada 31:369-372.

All species of North Atlantic fishes studied, with the exception of two groups of offshore lobsters, had total mercury levels less than the 0.5 mg/kg limit allowed for fish of commerce in Canada and the United States. There appeared to be no relationship between mercury levels and sex or weight of fish of any one species.

795. Freeman, R.A. 1973. Recovery of rainbow trout from aluminum poisoning. Trans. Amer. Fish. Soc. 102(1):152-154.

As a sequel to a recent series of constant-flow bioassay studies to determine toxicity of aluminum to rainbow trout, Salmo gairdneri, trout which had previously been exposed to various concentrations of aluminum were maintained for several additional months in absence of aluminum addition for detection of persistent effects. The bioassays had been designed to expose trout to aluminum concentrations and pH levels wherein soluble and precipitated forms of aluminum were present singly and in various combinations. Under some conditions of exposure, fish exhibited severe gill hyperplasia and darkening of coloration, did not feed, and suffered heavy mortality. Significant reductions in growth rates were also evident in conjunction with these symptoms.

796. Freeman, R.A., and W.H. Everhart. 1971. Toxicity of aluminum hydroxide complexes in neutral and basic media to rainbow trout. Trans. Amer. Fish. Soc. 100(4):644-658.

Toxic effects of aqueous aluminum complexes in neutral and basic media to rainbow trout fingerlings were investigated under constantly flowing, controlled conditions of concentration, pH, and temperature. Toxicities of various concentrations were highly pH dependent. Dissolved concentrations over 1.5 mg/l aluminum caused drastic physiological and behavioral aberrations as well as acute mortality. Toxic effects of suspended aluminum, while they are more noticeable, at lower concentrations, are not as concentration dependent as those of dissolved forms. The safe concentration of either dissolved or suspended aluminum is well below 0.5 mg/l. Mortalities among test animals ceased almost immediately after aluminum exposures were concluded. Recovery times for fish exposed to the various tests were proportional to the severity of the test conditions and to length of exposure. Normal growth resumed almost immediately in fish from the less severe tests, and after a period of a few weeks in fish from the more severe tests. After up to four months recovery the average weight of fish surviving both chronically and acutely toxic aluminum concentrations is markedly below the control average.

797. French, N.R. 1963. Review and discussion of barium. In Schultz, V., and A.W. Klement, Jr. (eds.). Radioecology. Reinhold Publ. Corp., New York: 557-560.

Isotopes of barium account for a sizable fraction of the activity in fresh fission products. They are readily assimilated by aquatic vertebrates and by invertebrates. They are concentrated by some insects, and perhaps by certain soil invertebrates. Mammals accumulate radiobarium in all tissues, and it is fixed in the bones. Radioactive barium may provide considerable radiation doses on a short-term basis to certain facets of the ecosystem.

798. Freyre, L. 1973. Pollution of the 'El Carpincho' Pond (Pampasic Region, Argentina) and its effects on plankton and fish communities. Environmental Pollution 4(1):37-40.

A pond in the Southern Pampasic region of Argentina, with highly developed fishing and other recreational activities, has been impacted since 1969 by effluents from 3 industrial plants (milk processing plant, plastic bag factory, and an establishment for washing cattle trucks). The effects of this on the plankton and fish communities were investigated. Chemical analyses showed an increase in Na and sulfite, nitrates and phosphates. Lead and iron were detected in the water for the first time, and there was a high BOD and chloride demand, with an objectionable odor in wastes from the milk industry. Changes in the Mg/Ca ratio caused a reduction in density of zooplankton, and in numbers of the freshwater argentine silverside fish (Basilichthys bonariensis). On the other hand, an explosive increase in catfish (Parapimelodus valenciennesi) was observed. The diversity index for the relative composition of the fish fauna rose from 0.3093 in 1966 to 1.9384 in 1970.

799. Fromm, P.O., and R.H. Schiffman. 1958. Toxic action of hexavalent chromium on largemouth bass. Jour. Wild. Manag. 22(1): 40-44.

LC-50 concentrations of hexavalent chromium to largemouth bass was 195 mg chromium/l under the conditions described. Exposure to 94 mg Cr/l caused initially a slight increase in oxygen consumption after exposure for 68 h. Exposure to chromium caused severe pathological changes in the intestine immediately posterior to the pyloric caeca that in all probability completely destroyed its digestive function. The normal respiratory rhythm of bass was not observably altered following exposure to chromium; however, coughing movements which occurred at fairly regular intervals were observed. No significant change in the histology of the gills of fish exposed to chromium was noted. In concentrations that are not acutely lethal, chromium apparently does not kill fish by interference with the respiratory function of the gill.

800. Fry, F.E.J., D. Cucin, J.C. Kennedy, and A. Papson. 1960. The use of lead versenate to place a time mark on fish scales. Trans. Amer. Fish. Soc. 89:149-153.

Satisfactory deposits of Pb in scales for time marks were produced without adverse effects in whitefish and lake trout by injection of 5%-7% Pb di-Na versenate at doses of 50 mg/kg wt.

801. Fukui, S., K. Tanaka, S. Kanno, and T. Ukita. 1972. Improvements in the determination method of methyl mercury in fish tissues and the ratio of methyl mercury to total mercury in fish tissues. Advances in Water Pollution Research, Sixth Int. Conf., Jerusalem, Israel, June 8-23, 1972:819-827.

New methodology was established for determination of the ratio of methyl mercury to total mercury in fish tissues. Using this technique, the ratio of methyl mercury to total mercury in one sample of spearfish was 80.3% and in albacore tuna, 66.6%.

802. Funk, W.H., F.W. Rabe, R. Filby, J.I. Parker, and J.E. Winner. 1973. Biological impact of combined metallic and organic pollution in the Coeur d'Alene-Spokane River drainage system. Available from Nat. Tech. Inf. Ser. as PB-222 946:1-187.

High metal concentrations (1000-7000 mg/kg Zn) in the bottom sediments of the middle and northern portions of the lake did not appear to substantially affect distribution of benthic chironomids or oligochaetes. Lake sediment cores taken across the delta region of the Coeur d'Alene River penetrated through the regions of high metallic concentration and allowed an average sediment deposition rate to be calculated. Algal toxicity tests showed the amount of Zn normally present in the Coeur d'Alene Lake and River and the Spokane River to be inhibitory to the algal test organism Selanastrum capricornutum. The water quality of the Spokane River was of good to excellent quality in all parameters tested except for high metallic content, especially Zn. Activation and atomic absorption analysis of the metallic content in tissues of the organisms in the Spokane River indicated that algae were the prime concentrators of Zn, Cd, Pb, Hg, Fe, and Mn. Algae and detritus consumers reflected high metallic concentrations. Analysis of fish tissues showed a considerably lower concentration of metals than the aquatic plants, insects, or algae. The fish, when collected, did not appear to be under stress leading to the belief that most of the metals--although present in relatively high concentrations in the tissues of the organisms tested--must be in a relatively innocuous state.

803. Gale, N.L., M.G. Hardie, J.C. Jennett, and A. Aleti. 1973.
Transport of trace pollutants in lead mining wastewaters.
Trace Substances in Environmental Health 6:95-106.

The New Lead Belt region of southeastern Missouri, located in a rural heavily wooded region of the Ozarks, became the world's largest lead mining district in 1970. Prior to the full development of the mines, the heavy metals content of area streams was insignificant, with background values for lead, copper, and zinc in the range of 1 to 20 µg/l. Because of natural conditions present there is little problem with dissolved heavy metals in regional streams. However, considerable quantities of finely ground mineral particles may escape flotation and tailings reservoirs and be transported through the aquatic environment, especially during periods of turbulence. In addition mine and particularly mill effluents sometimes contain nutrients which encourage the development of complex algal and microconsumer communities. These aquatic forms have been found to trap and assimilate lead in significant quantities. In streams receiving mine and mill effluent, there is an inverse relationship between the content of lead in the organisms of the first trophic level and distance downstream from the sources of contamination.

804. Gale, N.L., B.G. Wixson, M.G. Hardie, J.C. Jennett. 1973.
Aquatic organisms and heavy metals in Missouri's New Lead
Belt. Water Resources Bull. 19(4):673-688.

Since industrial development began, there have been a number of nuisance biological blooms in several small streams receiving effluent from mines and mills. The major constituents of the problem algal growths include a variety of stalked and nonstalked diatoms. Secondary blooms of Sphaerotilus reach problem proportions in some streams, particularly in the autumn. Finely ground rock flour and mineral particles escaping from tailings dams are trapped by the stream vegetation. Concentrations of lead, zinc, copper and manganese in the algal and bacterial mats are inversely related to distance downstream from the tailings dams. Consumer organisms, including crayfish, snails, aquatic insects, tadpoles, minnows and larger sunfish, were analyzed to determine the extent of dissemination and concentration of heavy metals through food chains. Insignificant concentrations of heavy metals were found in the consumer organisms studied, though in at least one problem stream the normal consumer organisms were markedly reduced in numbers.

805. Gallegos, A.F., and F.W. Whicker. 1972. Radiocesium retention by rainbow trout as affected by temperature and weight. Available from Nat. Tech. Inf. Ser., Springfield, Va., as COO-115642:1-25.

A laboratory aquarium system was developed to test effect of water temperature on Cs-137 accumulation pattern for trout stocked in a Colorado montane lake within the range of temperatures expected in the lake during the growing season. Weight was selected as the second correlate. Cs-134 retention was observed in fish at 5.0, 8.3, 12.7 and 18.3°C. Ten fish ranging in live weight from 30 to 200 grams were maintained as active feeders at all temperatures. Some fish resided in the aquarium for more than 200 days without showing signs of ill health. Weight of each fish was recorded after most radiocesium body burden determinations. Typical radiocesium retention patterns observed for a given temperature are presented. Waters heated from sub-optimum to optimum temperatures by thermal pollution can be expected to increase fish feeding rates and also their retention of radionuclides incorporated into growing tissues. These experiments imply that maximum cesium intake and retention by fish would be achieved at water temperatures which were optimal for food consumption and growth.

806. Gammon, J.R. 1970. The effect of inorganic sediment on stream biota. U.S. Environ. Protect. Agen., Rept. 18050 DWC:1-141.

Fish and macroinvertebrate populations fluctuated over a four year period in response to varying quantities of sediment produced by a crushed limestone (Ca + Mg) quarry. Light inputs which increased the suspended solids loads less than 40 mg/l resulted in a 25% reduction in macroinvertebrate density below the quarry. Heavy inputs caused increases of more than 120 mg/l including some deposition of sediment and resulted in a 60% reduction in population density of macroinvertebrates. Population diversity indices were unaffected by changes in density because most taxa responded to the same degree. Experimental introductions of sediment caused immediate increases in the rate of invertebrate drift proportional to the concentration of additional suspended solids.

The standing crop of fish decreased drastically when heavy sediment input occurred in the spring, but fish remained in pools during the summer when the input was very heavy and vacated the pools only after deposits of sediment accumulated.

After winter floods removed sediment deposits, fish returned to the pools during spring months and achieved levels of 50% normal standing crop by early June. Slight additional gains were noted during the summer even with light sediment input. Only spotted bass (Micropterus punctulatus) was resistant to sediment, but its growth rate was lower below the quarry than above. Most fish were much reduced in standing crop below the quarry.

807. Gardner, G.R., and G. LaRoche. 1973. Copper induced lesions in estuarine teleosts. Jour. Fish. Res. Bd. Canada 30:363-368.

Cellular changes attributable to copper were observed in mechanoreceptors of lateral line canals in the head of adult mummichog (Fundulus heteroclitus) and Atlantic silverside (Menidia menidia); epithelium of these canals was altered in mummichog. In both species, lesions were observed in olfactory organs, which included chemoreceptive sites. These manifestations of copper poisoning were evident at all studied concentrations: 0.5, 1.0, and 5.0 mg/l of Cu^{2+}. In silverside, dilation of blood vessels was apparent, and in five cases hemorrhage had occurred in brain and in periorbital connective tissues.

Renal lesions in mummichog exposed to 1.0 and 5.0 mg/l of copper were apparent; these changes could not be identified in silverside. Hepatic damage was not detectable by microscopy in either species following external exposures to copper. However, high levels of copper administered intraperitoneally to mummichog induced liver damage.

Fry of mummichog were more sensitive to copper than adults or zygotes. Emergence of larvae, time required for emergence, and posthatch survival was impaired by copper; there were no lesions in developing sensory areas of the lateral line or the olfactory systems in these immature stages.

808. Gardner, G.R., and P.P. Yevich. 1969. Toxicological effects of cadmium on Fundulus heteroclitus under various oxygen, pH, salinity and temperature regimes. Amer. Zool. 9(4):1096.

Histopathological responses of the killifish (Fundulus heteroclitus) to acute cadmium poisoning include changes in intestinal tract, kidney and blood as indicated by a rise in the percentage of eosinophils from 3% to 43%. Under conditions of $30^{o}/oo$ salinity, pH 7.8, dissolved O_2 of 7 mg/l, 20°C, and a monitored cadmium concentration of 50 mg/l, lesions occurred in intestine after one hour of exposure and in kidney after eight hours. Eosinophilia was observed in the peripheral blood after eight hours of exposure. Similar findings were obtained in specimens exposed to the relatively high cadmium concentration while a single environmental parameter was modified and others maintained constant. In one experiment the salinity was decreased to 15°/oo, in a second the pH was maintained at 4, in a third the temperature was raised to 30°C (oxygen maintained at saturation 4.5 mg/liter) and in a fourth experiment the oxygen content was reduced to 2 mg/liter while all other parameters remained constant. Although the same lesions were produced, the rate and order of incidence were altered. Kidney lesions occurred in nearly all animals, except in those exposed under low pH conditions where only 10% showed the lesions. Intestinal lesions were present in all animals exposed under low oxygen levels, and in approximately 50% of those exposed under the temperature and salinity modifications. The incidence of intestinal lesions (19%) were least at low pH. All specimens exposed showed severe eosinophilia (over 43% rise in eosinophil counts) except at 30°C in which an average rise of 30% in eosinophils was observed.

809. Gaskin, D.E., R. Frank, M. Holdrinet, K. Ishida, C.J. Walton, and M. Smith. 1973. Mercury, DDT, and PCB in harbour seals (Phoca vitulina) from the Bay of Fundy and Gulf of Maine. Jour. Fish. Res. Bd. Canada 30(3):471-475.

Samples of blubber, longissimus muscle, liver and cerebrum from 12 harbor seals were analyzed for DDT, dieldrin, PCBs, and total mercury content. The results were compared with those obtained previously for harbor porpoises (Phocoena phocoena). DDT and PCB levels appear to be of the same magnitude in the fat of seals from both southern New Brunswick and southern Maine, being lowest in a lactating female. Virtually no o,p-DDT and relatively little dieldrin were found in seal fat, in contrast to porpoises, which contained significant amounts of both in fat. Mercury levels were generally similar to those found for porpoises, but total liver Hg was considerably greater in adults from the New Brunswick islands than in those from the southern Maine ledges.

810. Gaskin, D.E., K. Ishida, and R. Frank. 1972. Mercury in harbour porpoises (Phocoena phocoena) from the Bay of Fundy Region. Jour. Fish. Res. Bd. Canada 29(11):1644-1646.

During 1969-71, 41 muscle and 20 liver samples were collected from harbor porpoises (Phocoena phocoena) in the Bay of Fundy region. These tissues were analyzed for total mercury content. Total Hg levels ranged from 0.21 to 1.92 mg/kg (average 0.75) in muscle tissue of males and from 0.26 to 2.58 mg/kg (average 1.02) in muscle tissues of females; from 0.89 to 18.3 mg/kg in liver tissue of males and from 0.55 to 91.3 mg/kg in liver tissue of females. Averages of the two latter series would be meaningless. A limited number (four muscle and six liver samples) of determinations of the methylated fraction were also made. In the muscle Hg was virtually 100% methylated; in the liver the methylated fraction varied from 7.4 to 41% being lowest in livers with highest total Hg.

810A. Gaskin, D.E., G.J.D. Smith, P.W. Arnold, M.V. Louisy, R. Frank, M. Holdrinet, and J.W. McWade. 1974. Mercury, DDT, dieldrin, and PCB in two species of Odontoceti (Cetacea) from St. Lucia, Lesser Antilles. Jour. Fish. Res. Bd. Canada 31:1235-1239.

Sample of blubber, muscle, liver, and kidney of short-finned pilot whale *Globicephala macrorhyncha* and long-snouted dolphin *Stenella* sp. from waters adjacent to St. Lucia, Lesser Antilles, were analyzed for Hg, DDT, dieldrin, and PCB. Total Hg levels were high, ranging from 1.33 to 5.36 mg/kg in muscle (methylated fraction 42-100%), 2.28 to 14.00 mg/kg in kidney (methylated fraction about 14%), and 13.00 to 157.00 mg/kg in liver (methylated fraction 2-17%). DDT in blubber ranged from 1.25 to 7.38 mg/kg, dieldrin in blubber from 0.007 to 0.04 mg/kg, and PCB in blubber from 0.69 to 5.00 mg/kg. The presence of the high Hg levels is attributed largely to natural sources, as the Lesser Antilles Island Arc is a site of intense cyclic tectonic activity. There may be some contribution from atmospheric sources. Both DDT and PCB could be largely the result of atmospheric transportation from higher latitudes, although local DDT spraying programs may have contributed. The circulation pattern in the Gulf of Mexico and Caribbean appears to rule out water-borne transport from the river systems of the Gulf States of the United States.

811. Ghiretti, F., B. Salvato, S. Carlucci, and R. DePieri. 1972. Manganese in *Pinna nobilis*. Experientia 28(2):232-233.

Manganese in the bivalve mollusk *P. nobilis* collected from the Adriatic Sea was determined by chemical and X-ray fluorescence. Consistent amounts of Mn were found in kidney, and some Mn was found in the byssus. Manganese found in the kidney is almost entirely confined to nephrolith bodies.

812. Gibbs, P.E., and G.W. Bryan. 1972. A study of strontium, magnesium, and calcium in the environment and exoskeleton of decapod crustaceans, with special reference to *Uca burgersi* on Barbuda, West Indies. Jour. Exper. Mar. Biol. Ecol. 9(1):97-110.

Analyses of samples from Barbuda, Leeward Islands, show that the Sr-Ca atom ratio of the exoskeleton of the fiddler crab (U. burgersi) is proportional to that of the environment, while the Mg-Ca atom ratio is fairly constant regardless of the environmental ratio. Laboratory experiments on Carcinus maenas demonstrate that the Sr-Ca atom ratio of the exoskeleton is, to a large extent, determined by the ratio in the environment at the time of new skeleton deposition. Most brachyuran crabs have similar distribution coefficients, and major variations in the Sr-Ca atom ratio can be related to differences in the environmental ratio.

813. Giblin, F.J., and E.J. Massaro. 1973. Pharmacodynamics of methylmercury in rainbow trout (Salmo gairdneri): Tissue uptake, distribution, and excretion. Toxicol. Appl. Pharmacol. 24(1):81-91.

The tissue distribution, rate of uptake and concentration of 203 Hg-labeled methylmercury was investigated in 20 different tissues and organs over a period of 100 days following single intragastric dose of 0.5 mg Hg/kg body weight. After 1 hr, mercury concentration factors > 0.1 were detected in the blood, heart, liver, spleen and kidney; a concentration factor (CF) of 1.0 equals mercury concentration in dose. Highest mercury concentrations (CF > 7.0) were observed in the blood at 7 days and spleen at 14 days. After 100 days, the CF of the blood was > 2.0 and the CF values of the spleen, kidney and liver were > 1.0. Maximum CF values were reached in the skeletal muscle, brain and lens after 34, 56 and > 90 days, respectively. Maximum values were reached in most other tissues and organs at approximately 7 days. Skeletal muscle appeared to function as a reservoir for methylmercury and accumulated 50% of the dose from 34 to 100 days post administration. Methylmercury accumulation in the brain was limited to 0.1% of the dose. The rate of mercury excretion appeared to be biphasic as a result of a slow elimination from the skeletal muscle relative to the other tissues and organs. Employing both the slow and fast rate, the half-retention time for methylmercury in rainbow trout was estimated to be > 200 days.

814. Gibson, C.E., 1972. The algicidal effect of copper on a green and a blue-green alga and some ecological implications. Jour. Appl. Ecol. 9(2):513-518.

An algicidal dose of copper sulphate was applied to Cefni Reservoir, North Wales, to remove Anabaena flos-aquae, the dominant species. It was quickly replaced by Scenedesmus quadricauda, previously a minor plankton constituent. To explain this phenomenon and to elucidate copper effect on the two algae, laboratory studies were undertaken. Anabaena and Scenedesmus were exposed to several different concentrations of copper sulphate. *A. flos-aquae* was more sensitive to copper than *S. quadricauda* and accumulated more copper. Lethal concentration of accumulated copper was similar for both species. Sensitivity of *A. flos-aquae* to copper varied with the stage of its growth, becoming less sensitive as the culture aged. Although copper sulphate is more effective as an algicide when used against *A. flos-aquae*, other conditions being equal, a greater amount of the copper applied will be trapped in its cells and settle to the bottom. Build-up of copper on the bottom sediment, not studied in detail, may be of the order of four or five times faster from dead *A. flos-aquae* than from *S. quadricauda*, making more acute the danger of adversely affecting the bottom fauna and probably the whole food web.

815. Gilderhus, P.A. 1966. Some effects of sublethal concentrations of sodium arsenite on bluegills and the aquatic environment. Trans. Amer. Fish. Soc. 95:289-296.

Bluegills were exposed to sodium arsenite at various concentrations and treatment frequencies in outdoor pools. The effects of the treatments on the fish and invertebrates in the pools were assessed. Applications totaling 4.0 mg/l or more of $NaAsO_2$ during the experiment were reflected in reduced survival and growth of the fish, with immature fish being affected to a greater degree than adults. Some pathological changes were observed in adults. Arsenic residues were found in water, bottom soil, and throughout organs and flesh of bluegills at termination of the experiment. Bottom fauna and plankton populations were reduced or inhibited in several pools exposed to the highest concentrations of the herbicide.

816. Gillespie, D.C. 1972. Mobilization of mercury from sediments into guppies (*Poecilia reticulata*). Jour. Fish. Res. Bd. Canada 29(7):1035-1041.

Guppies were exposed in aquaria to aerobic and anaerobic sediments to which various forms of mercury were added and to sediments from two sites of industrial pollution. Whole body levels of total mercury in these fish were used as a measure of mobilization of mercury from sediments. Spot checks for methylmercury were carried out at intervals during the tests. Under aerobic conditions there was little mobilization of mercury from sediments to which mercuric chloride or sulphide had been added but total mercury concentrations rose rapidly in fish exposed to sediments containing metallic mercury.

The proportion of methylmercury in fish reached maxima of 30% for metallic mercury, 40% for mercuric chloride, and 45% for mercuric sulphide. In anaerobic sediments, total mobilization was low and only mercuric chloride was significantly methylated (40% of the total in the fish).

Both mobilization and methylation were proportionately greater in industrial sediments with a low mercury content than in sediments with a higher mercury content. Enrichment of sediments with lignosulphonate showed no real effects aerobically, possibly because of the chelation properties of the preparation used. Anaerobically, lignosulphonate stimulated methylation of mercury.

The levels of mercury and methylmercury found in fish are consistent with data from nature.

817. Gillespie, D.C., and D.P. Scott. 1971. Mobilization of mercuric sulfide from sediment into fish under aerobic conditions. Jour. Fish. Res. Bd. Canada 28(11):1807-1808.

A system for studying the aerobic mobilization of mercury from aquatic sediments into fish was described. Using this method, it was shown that mercuric sulfide in sediment was very slowly mobilized and picked up by fish.

818. Gloyna, E.F., Y.A. Yousef, and T.J. Padden. 1971. Radioactivity transport in water. Continuous release of radionuclides in a small scale ecosystem. U.S. Atom. Ener. Comm. Contract AT(11-1)-490, Tech. Rept. 21, CRWR-75, EHE-71-1, ORO-21:1-66.

Radionuclide uptake by rooted aquatic plants, suspended phytoplankton, and bottom sediment was studied in a model river system for which radionuclide concentrations in water were below the guidelines. Rooted plants reached a quasi-equilibrium activity in 36 hours as compared to 30 days for bottom sediments. Suspended phytoplankton concentrations averaging about 20 mg/liter increased the transfer rate to bed sediments about 25%. The ratio of the radioactivity per g (dry weight) to that per ml water at quasi-equilibrium for rooted plants averaged 600 for Sr-85 and 400 for Cs-134. The ratio for phytoplankton was 200-700 for Sr-85 and 4,000-13,000 for Cs-134. Uptake of Cs-134 (but not of Sr-85) by phytoplankton was linearly related to the rate of photosynthetic oxygen production. The ratio of radioactivity per sq cm of sediment to that per ml of water was 70-90 for Sr-85 and 250-300 for Cs-134.

819. Gonye, E.R., Jr. 1972. The abnormal morphogenesis of *Arthrobacter marinus* under heavy metal stress. Ph.D. Thesis: 1-173.

Avail. from Univ. Microfilms, Inc., Ann Arbor, Mich. 48106. Order No. 73-4358.

Arthrobacter marinus exhibits alteration of its normal coccoid-rod morphogenesis in the presence of heavy metal ions. Ni caused the most dramatic alterations of cellular morphology at a concentration of 0.0002 to 0.0004 M $NiCl_2$ in a basal medium. Under Ni stress the cell enlarged in diameter from a normal 1-2 to over 25 millimicrons. In comparison to bacterial cultures of a non-marine origin related to the genus *Arthrobacter*, *A. marinus* demonstrated tolerance to the highest concentrations of Ni (0.0005 M) in nutrient agar. Only *A. marinus* formed megalomorphic cells in the presence of $NiCl_2$ concentrations approaching toxicity. In the Ni-stressed condition a loss of cell envelope amino acids including alanine, glutamic acid and diaminopimelic acid was observed. Ferrichrome, putrescine, and spermidine were ineffective in sparing megalomorphic formation of *A. marinus* under Ni stress. Scanning electron microscopy by the freeze-etching technique indicated multivacuolation characterized by vacuole membranes, polybeta-hydroxybutyric acid granules, and a loss of cell envelope protein granules under Ni stress. An ecological survey of three seawater environments, open ocean, coastal, and estuarine, indicated the open ocean heterotrophic microbial population as the most Ni tolerant.

820. Gordon, C.M., R.A. Carr, and R.E. Larson. 1970. The influence of environmental factors on the sodium and manganese content of barnacle shells. Limnology and Oceanography 15(3):461-466.

Sodium and manganese in barnacle shells, collected from habitats with salinities varying from 1-26^{o}/oo, have been measured by neutron activation analysis. Sodium content varies from 1,600 to 5,000 mg/kg and is proportional to environmental salinity. Manganese values range from 80 to 3,800 mg/kg and are related to the concentration of manganese in the local water.

821. Graham, D.L. 1972. Trace metal levels in intertidal mollusks of California. Veliger 14(4):365-372.

Silver, cadmium, chromium, copper, manganese, lead and zinc levels in 7 species of mollusca (of the genera *Acmaea*, *Tegula*, *Thais*, *Mytilus*, *Protothaca* and *Tapes*) were determined for eleven regions along the California coast from San Francisco Bay to Los Angeles. Separate analyses were performed on shells and soft portions of whole bodies. Over 900 mg/kg lead were found in the bodies of *A. digitalis*: 570 mg/kg copper and 1700 mg/kg zinc were found in the bodies of *Thais emarginata*.

822. Gramenitskii, E.M. 1958. Effect of lead nitrate on the supravital staining of cells of poikilotherms. Bull. Exp. Biol. Med. USSR, 45:97-100.

Effect of Pb nitrate was studied on various cells of liver, kidneys, and nerves of frogs using a technique of supravital staining in situ with neutral red. Threshold paranecrotic doses of Pb nitrate were: liver cells, 3 mg/g body weight; kidney tubule cells, 7 mg/g body weight; and sympathetic nerve cells, 10 mg/g body weight. Paranecrotic changes were not revealed in the sensory nerve cells of the spinal ganglia, although reflex activity of the laboratory animals was depressed. A supravital staining technique, consisting of injection into the body cavity of 1% aqueous neutral red solution at dose levels of 0.3-0.5 mg dye/g body weight and removal and examination of organs within 1 hr after injection, is recommended for use in toxicology.

823. Gray, J.S., and R.J. Ventilla. 1973. Growth rates of sediment-living marine protozoan as a toxicity indicator for heavy metals. Ambio 2(4):118-121.

The classical method for measuring toxicity of a chemical to a marine organism is by the LC-50 test. In this test the concentration which kills 50% of the test organisms in 48 or 96 hours is determined and is frequently used to set upper limits for concentrations in effluent discharge. The test can be criticized on a number of points: a) the duration of the test is too short, when effluent discharge will be continuous; b) should the organism survive the test, it may not grow and reproduce at the tested concentration and in nature the organism may avoid that concentration of chemical important to migratory fish and shellfish; c) on the assumption that toxicity increases with temperature, summer temperatures are used in the test, whereas stress conditions may be greater at lower temperatures; d) the organisms used are frequently at high trophic levels and are adults, whereas lower trophic levels and larvae are known to be more susceptible; e) chemicals are tested singly, whereas in nature mixtures of chemicals occur. In an attempt to allay such criticisms we have used an organism of low trophic level, a bacterivorous ciliate, and have measured changes in growth rate rather than mortality as criteria of pollution.

Using factorial designs and response surface analysis, experimental conditions were optimized with respect to salinity-temperature combinations. With near optimum conditions the effects of mercuric ions ($HgCl_2$), lead ions ($Pb(NO_3)_2$) and zinc ions ($ZnSO_4$) were tested each at three concentrations in a factorial design. $HgCl_2$ at an added concentration of 0.0025 mg/l reduced growth rate by 9.7%, $Pb(NO_3)_2$ at 0.15 mg/l by 8.5% and $ZnSO_4$ at 0.125 mg/l by 8.3%. On mixing the chemicals, significant supplemental synergistic effects were found at all two factor and three factor combinations. Models of the effects and graphical response surface contours are given. Since many chemicals are likely to interact, both supplementally or antagonistically, the method used seems of widespread relevance to toxicity testing.

824. Greichus, Y.A., A. Greichus, and R.J. Emerick. 1973. Insecticides, polychlorinated biphenyls and mercury in wild cormorants, pelicans, their eggs, food and environment. Bull. Environ. Contamin. Toxicol. 9(6):321-328.

Mercury residues were not detected in water, bottom sediments or fish except carp which also had the highest levels of insecticides and PCB residues. Concentrations of total mercury in lake trout were found to increase with the age of the fish and ranged from 0.19 to 0.66 mg/kg.

Insecticide and PCB levels in cormorant eggs appeared to reflect body levels but in pelican eggs they did not.

Mercury was highest in liver of cormorants and pelicans. Concentration factors of 14- and 6-fold over fish were found in bodies of cormorants and pelicans respectively. This may reflect greater mercury contamination in the food of cormorants in the wintering areas as the concentration in nestling cormorants was only 1.3 times that of fish. Cormorant eggs had higher levels of insecticides, PCB's and mercury than pelican eggs.

825. Greve, P.A., and S.L. Wit. 1971. Mercury in fish-total content in freshwater and marine fishes. TNO-nieuws 26:395-399.

Several species of marine and freshwater fishes were analyzed for mercury. In freshwater fish, Hg content was dependent on place of origin, with Usselmeer eel having more mercury than eels from other sources, averaging 0.5 mg/kg Hg. The biological accumulation factor for eel was about 1000; in other words, a 0.1 μg/kg Hg concentration in water would produce 0.1 mg/kg Hg in an eel. Similar factors have been found by Swedish researchers for pike and bass. Swedish standards for mercury content in fish tissue (1.0 mg/kg Hg) versus American standards (0.5 mg/kg Hg) are discussed.

826. Griffiths, R.P., and R.Y. Morita. 1973. Salinity effects on glucose uptake and catabolism in the obligately psychrophilic marine bacterium Vibrio marinus. Marine Biology 23:177-182.

Studies on effects of various salinities on uptake and catabolism of glucose in Vibrio marinus MP-1 revealed several significant shifts in total uptake and respiration as the cells were subjected to increasingly greater concentrations of NaCl. As the salinity increased from 0.30 to 1.0 M NaCl, there was a decrease in the $C_6/C_1(CO_2)$ ratio. Resulting patterns suggest that the relative participation of the hexose monophosphate pathway in glucose catabolism was altered. This pathway is apparently shut down in the region of the minimum-growth salinity, and may be related to growth limitation at lower salinities. The shift in C_6/C_1 ratio was not affected by changing incubation temperature, nor was it dependent specifically on presence of Na+ or Cl-. As salinity increased from 0.15 to 0.30 M NaCl, there was a shift in total uptake patterns which suggests the formation and loss of metabolic by-products derived from the first, second, sixth, and presumably fifth carbons of glucose.

827. Guinn, V.P., and R. Kishore. 1972. Results from multi-trace element neutron activation analyses of marine biological specimens. Available from Nat. Tech. Inf. Ser., Springfield, Va., as CONF-721010-10:1-5.

In Pacific Ocean mammals and large fish, much higher levels of Se and Zn were found in liver than in muscle tissue. With mammals the same was the case for Hg; however, with fish the level of Hg was about the same in both liver and muscle tissue. There was appreciable variation between different specimens of the same species and size, and even within a given tissue of a single specimen--such that it is important that large numbers of samples are analyzed. Levels as low as 0.01 mg/kg Hg, 0.02 mg/kg Se, and 0.2 mg/kg Zn could be detected using Ge (Li) gamma spectrometry.

828. Haga, Y., H. Haga, T. Hagino, and T. Kariya. 1970. Studies on the post-mortem identification of the pollutant in the fish killed by water pollution. XII. Acute poisoning with mercury (1). Bull. Japan. Soc. Sci. Fish. 36(3):225-231.

Toxicity and residues of mercury in goldfish killed by inorganic mercury in solution ($HgCl_2$) was determined. The 48 hour LC-50 was between 0.5 and 1.0 mg/l. Five mg/l of Hg was fatal in about 10 hours.

829. Hagerman, L. 1973. Ionic regulation in relation to the moult cycle of Crangon vulgaris (Fabr.) (Crustacea, Natantia) from brackish water. Ophelia 12:141-149.

Ionic regulation of haemolymph during the moult cycle of shrimp was investigated at $10^{o}/oo$ salinity. Sodium showed a minimum immediately after ecdysis and a maximum in the intermoult stages, while potassium, which also is held at a level higher than the medium, showed a minimum in the intermoult stages and an increase prior to and after ecdysis. Calcium showed, contrary to species from fully marine areas, a minimum after ecdysis and then a rapid increase in calcium ion concentration and a slow decrease in the later intermoult phase and in the premoult stages. Magnesium, generally held at a very low concentration, showed an increase at ecdysis. Chloride varied in the same way as sodium. The changes in ion concentrations during the moult cycle can mostly be explained by an increased permeability and an increased water intake before the ecdysis and a swelling of the animal after ecdysis before the new exoskeleton has hardened.

830. Hagerman, L. 1973. Ionic regulation in Crangon vulgaris (Fabr.) (Crustacea, Natantia) from brackish water. Ophelia 12:151-157.

The hyper-hypoosmotic (isosmotic at $23^{o}/oo$) shrimp was found to maintain Ca^{2+} and K^{+} more concentrated than the medium in $5\text{-}25^{o}/oo$, Na^{+} and Cl^{-} more concentrated in the range $5\text{-}30(23)^{o}/oo$ and less concentrated in higher salinities. Mg^{2+} was held at a very low level throughout the salinity range. The importance of various mechanisms (low permeability, active ion transport and hypo-osmotic urine) in assisting this efficient ion regulation is discussed.

831. Hakonson, T.E., A.F. Gallegos, and F.W. Whicker. 1972. Use of Cs-133 and activation analysis for measurement of Cs kinetics in a montane lake. Available from Nat. Tech. Inf. Ser., Springfield, Va., as COO-1156-41:1-17.

Uptake of Cs-133 by amphipods and zooplankton was measured by neutron activation. The concentration factor for both groups was about 340. Retention of Cs-134 by fish was determined by whole-body counting after injection by gavage. The temperature for maximum retention was that which was optimum for growth.

832. Haley, G.F., and M.A. Gibson. 1971. Calcium storage in the soft tissues of freshwater gastropods. The influence of environmental calcium concentrations. Canadian Jour. Zool. 49:1001-1004.

Effect of environmental calcium concentration gradients on storage of calcium spherules in Helisoma duryi eudiscus was investigated.

Primary sites of calcium storage in adult snails are the subepithelial connective tissues of the mantle edge, pulmonary region and foot. Snails were hatched and raised for 6 weeks in one of seven solutions of different calcium concentrations. These calcium chloride solutions contained the following concentrations of calcium: 10, 20, 40, 80, 160, 320, and 640 mg/l of demineralized water. A significantly higher number of calcium spherules are stored at both extremes of this concentration range, that is, in the 10, 320, and 640 mg/l solutions. The effects of the intermediate concentrations on calcium storage are not significantly different with respect to each other. No mention is made of the potential effects of demineralized water on snails.

833. Hannan, P.J., and C. Patouillet. 1972. Effect of mercury on algal growth rates. Biotechnology and Bioengineering 14:93-101.

Comparisons of the effects of 0.1 mg/l of mercury and other metallic ions (silver, cadmium, lead, copper) on the growth rates of one freshwater (*Chlorella pyrenoidosa*) and three marine algae (*Phaeodactylum tricornutum*, *Cyclotella nana*, *Chaetoceros galvestonensis*) have been made under controlled laboratory conditions. Growth, determined by an increase in fluorescence, was monitored using a fluro microphotometer. Fluorescence was measured initially and once each day for three days. Mercury was more toxic than the other metals tested; mercury as mercuric chloride was more toxic than dimethyl mercury. The toxicity of mercury was found to be comparatively irreversible and to vary inversely with the concentration of nutrients present in the growth media. Just how much mercury algae can absorb without growth inhibition is yet to be determined.

834. Hannan, P.J., N.P. Thompson, C. Patouillet, and P.E. Wilkniss. 1973. ^{203}Hg as tracer in pigments of *Phaeodactylum tricornutum*. Inter. Jour. Appl. Radiation Isotopes 24:665-670.

Cells of *Phaeodactylum tricornutum* were exposed to 0.12 mg/l Hg (containing Hg-203 as a tracer) in a 3.5% NaCl solution and in dilute culture medium of the same salinity. Radioactivity measurements indicated that mercury uptake by the algal cells was comparable in both solutions, and that less than 2% of the sorbed mercury was in the pigments, as determined by methanol extraction. The fluorescence of the cells, however, was decreased by either the presence of mercury or the absence of nutrients.

835. Hannan, P.J., P.E. Wilkniss, C. Patouillet, and R.A. Carr. 1973. Measurements of mercury sorption by algae. U.S. Naval Res. Lab., Wash. D.C., Rept. 7628:1-26.

Results of laboratory experiments concerning mercury sorption by two marine algae, Phaeodactylum tricornutum and Chaetoceros galvestonensis are described. Mercury uptake was determined using carrier-free Hg-197, and Hg-203 incorporated in mg mercury/liter concentrations. Significant mercury concentrations were found in cells grown in media prepared from chemically pure reagents; concentrations of 14 to 116 mg/kg were present in cells harvested from 10% and 100% concentrations of culture medium. Phaeodactylum cells grown in a 10% culture medium in the presence of 0.05 mg Hg/l contained 2400 mg Hg/kg but growth was inhibited only 55% in a 4-day period. Chaetoceros cells had a greater affinity for mercury and contained over 7400 mg Hg/kg when cultured for the same time period in a 25% culture medium containing 0.10 mg Hg/l. They had not grown, as determined by fluorescence analysis.

Mercury sorption to Millipore filters was greater in the presence of dilute culture medium than in 3.5% NaCl solution. To circumvent the problems associated with this phenomenon, a procedure was devised whereby the activity of isotopically tagged cells could be determined without collecting them on a filter. Less than 2% of the mercury sorbed to Phaeodactylum cells was in the pigments.

836. Hanson, W.C., and A.C. Case. 1963. A method for measuring waterfowl dispersion utilizing phosphorus-32 and zinc-65. In Schultz, V., and A.W. Klement, Jr. (eds.). Radioecology, Reinhold Publ. Corp., New York: 451-453.

Waterfowl which inhabit the Columbia River within and downstream from the Hanford Reservation accumulate small amounts of radionuclides from reactor effluent released to the river. A method is described for identifying these birds in the hunter harvest. Waterfowl heads were rapidly scanned for total gamma radiation, due principally to zinc-65, and those with above-background counting rates subsequently were associated with the Hanford section of the Columbia River by analyses for phosphorus-32.

The phosphorus-32 tag was detected in 41% of 601 waterfowl harvested within a 50 mile radius of the Hanford Reservation during the 1960-1961 hunting season. Initial results showed seasonal fluctuations in the tagged portion of the population with three major arrival periods of unmarked immigrants.

837. Hardisty, M.W., S. Kartar, and M. Sainsbury. 1974. Dietary habits and heavy metal concentrations in fish from the Severn Estuary and Bristol Channel. Marine Poll. Bull. 5(4): 61-63.

Comparisons of growth rates, feeding habits, and heavy metal levels of flounders from Barnstaple and Oldbury-on-Severn have shown that at all ages the fish from Barnstaple are larger than those from the middle Severn estuary and that there are marked differences in diet. These differences in diet may contribute to the much higher zinc levels of the Barnstaple flounder samples. In the six other fish species examined, there is a distinct correlation between cadmium concentrations of the tissues and the proportion of crustaceans in the diet. Lead concentrations appear to follow a similar trend, but no relationship could be detected between diet and tissue zinc levels.

838. Harrison, F.L. 1973. Accumulation and loss of cobalt and caesium by the marine clam, Mya arenaria, under laboratory and field conditions. In Radioactive Contamination of the Marine Environment, Int. Atom. Ener. Agen., Vienna, Austria: 453-478.

The accumulation of Co-60 and Cs-137 by clams was followed in the laboratory in aquarium systems in which the levels of radioactive and stable caesium and cobalt were held constant. At 3- to 21-day intervals during the 6-month accumulation period, groups of 8 animals were removed from the water and their soft tissues were dissected into 7 different organs and tissues. The concentrations of both Co-60 and Cs-137 in the edible tissues increased rapidly and then levelled off at concentrations of Co-60 that were about 200 times that of water and of Cs-137 that were about 5 times that of water. Variations in concentration among body parts were larger for Co-60 than for Cs-137. The effect of stable element concentration in water on accumulation rates was assessed in groups maintained in seawater containing 0.5, 2.5, and 12.5 μg/l each of stable cobalt and caesium. Little regulation of caesium accumulation was observed at these concentrations; the rates of accumulation increased with the concentration in water. Some regulation of cobalt occurred at the higher concentrations. The accumulation of Co-60 and Cs-137 was followed also in clams introduced into a discharge canal receiving radioactive waste from a boiling-water reactor. Groups of 6 animals were sampled at 3-week intervals and concentrations were measured in the pooled, total soft tissues. Loss of Co-60 by whole clam was monophasic, that of Cs-137 was biphasic. Kinetics of accumulation and loss were described by exponential equations. The rate constants of accumulation and loss and the steady-state concentration factors are being used in models to predict the dose to man from the consumption of animals exposed to radioactive releases.

839. Harriss, R.C., D.B. White, and R.B. MacFarlane. 1970. Mercury compounds reduce photosynthesis by plankton. Science 170(3959): 736-737.

Concentrations of organomercurial fungicides as low as 0.1 µg/l in water reduced photosynthesis and growth in laboratory cultures of one species of marine diatom and several natural phytoplankton communities from Florida lakes. The acute toxicity of mercury compounds to phytoplankton is dependent on the chemical nature of the mercury compound and on cell concentrations.

840. Harvey, R.S. 1967. Effects of temperature on the sorption of radionuclides by a blue-green alga. Symposium on Radioecology, Proc. 2nd Natl. Symp., Ann Arbor, Mich.: 266-269.

Temperature differential effects (15°C) on sorption of cesium-137, strontium-85, zinc-65, iron-59, cobalt-57, and manganese-54, by the filamentous Cyanophyte, *Plectonema boryanum*, are reported. The alga was collected from reactor effluent streams. Unialgal cultures were grown concurrently at four water temperatures and samples weighed and radioassayed after exposures of increasing times. This species grew best between 30 and 40°C. Growth was not affected by low concentrations of radionuclides in the medium. Radionuclide concentrations at the various water temperatures were compared; for a given water temperature, sorption levels differed for the radionuclides studied because of variances in specific activity and biological demand for various elements. The essential elements of manganese-54, zinc-65, cobalt-57, and iron-59, were sorbed to higher levels than strontium-85 and cesium-137, perhaps due in part to their physical state; only cesium-137 and strontium-85 were present, mainly in ionic form. Since sorption levels for the various radionuclides were raised or lowered by factors less than 2.5 by the temperature differential, the conclusion was drawn that nonlethal variations in water temperature have no major influence on the sorption by *P. boryanum* of the radionuclides tested.

841. Hasler, A.D. 1949. Antibiotic aspects of copper treatment of lakes. Trans. Wisconsin Acad. of Sci., Arts, Letters 39:97-103.

Lakes, in a comparatively short time, move toward a eutrophic stage in which massive algal developments may be anticipated. Such algal growths inhibit many of the recreational and other human uses made of the lakes and of their waters. The spray application of copper sulfate solution has been found effective in inhibiting development of algal blooms. However, addition of copper through sprays may introduce a toxic condition. Results of short exposures of fish to copper salt toxicity do not reflect the impact of toxic effects over longer periods. Algae, fish, invertebrates, and amphibians are all subject to inhibi- or destruction by the absorption of copper salts. The author suggests that studies be undertaken to substitute other control substances for a permanent poison that has been employed to combat a temporary nuisance. Harvesting of crops of algae and large aquatic plants might be a control mechanism, as might zoning of lakes for certain specific uses, and various kinds of watershed controls.

842. Hata, Y. 1960. Influence of heavy metals upon the growth and activity of marine sulfate-reducing bacteria. Norinsho Suisan Koskusho Kenkyu Hokoku 9:363-375.

Marine sulfate-reducing bacteria strain SM1 was used throughout this work. Heavy metals originally contained in peptone and lactic acid employed were removed by use of the 8-quinolinol treatment. When salts of Bi, Co, Cr, Mn, Pb, and Sb were present in culture media, sulfides were accumulated in higher concentration than in absence of these metal salts, although initial growth of bacteria was considerably retarded when compared with the latter case. Results suggest that the above metals acted as inhibitors of bacterial growth, and also as precipitators of free H_2S produced. Removal of free H_2S by precipitation from the media has a favorable effect upon the sulfate-reducing activity of these bacteria.

843. Havre, G.N., B. Underdal, and C. Christiansen. 1972. The content of lead and some other heavy elements in different fish species from a fjord in western Norway. Proc. Inter. Symp. Environ. Health Aspects of Lead, Amsterdam, Oct. 2-6, 1972: 99-111.

The investigation deals with uptake and accumulation of heavy elements, especially lead and cadmium, by animals living in a polluted fjord on the western coast of Norway. The source of pollution in this connection is a zinc factory at the inner end of the fjord. The content of lead, cadmium, zinc and mercury are determined in a number of fish, caught at different localities along the fjord. The zinc content is of interest because it seems to have influence upon the uptake of other heavy elements. The figures for lead, cadmium and zinc are discussed in correlation to each other, and in correlation to fish species. It was concluded that zinc uptake in fish from a polluted area like this is not seriously affected, while uptake of lead is raised more than ten times when zinc and lead outlets in the sea are about the same. When the outlet of lead in the sea is more than 100 times higher than the outlet of cadmium, the content in fish liver is about the same for the two elements, in fact slightly higher for cadmium, while content in fish muscles is about ten times higher for lead than for cadmium.

844. Havre, G.N., B. Underdal, and C. Christiansen. 1973. Cadmium concentrations in some fish species from a coastal area in southern Norway. Oikos 24:155-157.

Cadmium concentrations in some fish species have been determined using atomic absorption. Concentrations were low, varying from 0.003 to 0.012 μg/g wet weight in cod, and from 0.002 to 0.029 μg/g, and 0.003 to 0.033 μg/g in whiting and herring, respectively. Results could indicate a slightly greater accumulation of cadmium in fat fish as compared to lean fish. No correlation seems to exist between the cadmium concentration and the total weight of the fish.

845. Hayashi, A. 1960. Biochemical studies on *Ostrea gigas*. IX. Lead content. Seikagaku 32:871-873.

Seasonal changes of the Pb content in *Ostrea gigas* were determined. Except for September when the Pb content was 5.9 mg/kg of fresh tissue, rather constant values, ranging from 0.1-0.4 mg/kg were obtained. Different culture methods did not influence the Pb content. Distribution of Pb was highest in the mantle (in mg/kg of ashed sample).

846. Hayward, J. 1970. Studies on the growth of *Phaeodactylum tricornutum*. VI. The relationship to sodium, potassium, calcium and magnesium. Jour. Mar. Biol. Assn. U.K. 50:293-299.

Experiments were conducted to determine cellular concentrations of Na, K, Mg, and Ca in *Phaeodactylum*. Evidence is presented showing that the ionic concentrations vary during different phases in batch culture and that algal cells become relatively richer in divalent cations towards the end of the growth period. Variation in external concentration has little effect on internal concentration of the cations studied and a hypothesis is suggested to account for the faster rate of growth in more dilute medium.

847. Hearnden, E.H. 1970. Mercury pollution. Fisheries of Canada 22(10):3-6.

In November, 1969, a report made by the Saskatchewan government disclosed that abnormal levels of mercury had been detected in fish from the Saskatchewan River. The fish from the river were immediately taken into custody and those lots with over 0.5 mg/kg of mercury were destroyed. About 500,000 kg were incinerated. The mercury was traced to a chlor-alkali plant. With 14 of these plants operating across Canada an intensive monitoring program was undertaken. Some additional areas were closed to fishing because of mercury pollution. Steps have been taken to control and eliminate the mercury pollution problem in Canada.

848. Hecky, R.E., and P. Kilham. 1973. Diatoms in alkaline, saline lakes: ecology and geochemical implications. Limnology and Oceanography 18(1):53-71.

Six species of diatoms achieved dominance in 26 alkaline, saline lakes in East Africa. There is a pronounced tendency for these species to replace each other as alkalinity increases, *Cyclotella meneghiniana* is usually dominant in less concentrated lakes and *Nitzschia frustulum* is favored as the alkalinity exceeds 80 meq/liter. *Coscinodiscus rudolfi* and *Navicula elkab* are occasionally dominant at intermediate alkalinities. *Navicula elkab* is usually subdominant when *N. frustulum* is dominant. Most of these species when dominant are considered functionally planktonic in these waters. The presence of the cyanophyte *Oscillatoria* (*Arthrospira*) *platensis* in bloom seems to be a prerequisite for *N. elkab* and *N. frustulum* to enter the plankton. There is some evidence that the anionic composition of these lakes may be selective for some of the benthonic species. Geochemical data indicate that the production and preservation of diatom frustules appear to control silica concentrations in the waters. Relatively poor correlations were observed between sodium and silica and between pH and silica. These data have important implications for theoretical models of geochemical evolution in closed basins. Little or no dissolution of fossil diatom frustules was observed in the sediments of these highly alkaline, high pH waters.

849. Heft, R.E., W.A. Phillips, H.R. Ralston, and W.A. Steele. 1973. Radionuclide transport studies in the Humboldt Bay marine environment. *In* Radioactive Contamination of the Marine Environment, Int. Atom. Ener. Agen., Vienna, Austria: 595-614.

Operation of the Pacific Gas and Electric Company nuclear power reactor (65 MW(e) boiling water) at Humboldt Bay, Eureka, California, produces as a by-product in low concentration in aqueous solution a number of radionuclides (fission products, Zn-65, Co-60, Mn-54, H-3, etc.). At irregular intervals the accumulated radioactive liquid waste is released into the Bay in accordance with limits prescribed by the Atomic Energy Commission and the State of California North Coastal Regional Water Control Board. The Lawrence Livermore Laboratory, in cooperation with the Pacific Gas and Electric Company has undertaken a program to study the transport of the released radionuclides through the Humboldt Bay marine environment. The Bay is considered to be divided into five aqueous pools. Within each pool, the radionuclides are partitioned among some or all of the following compartments—aqueous solution, bottom sediment, suspended sediment, benthic algae, eelgrass, phytoplankton. The experimental program consists of three main parts: assay of each release for gamma-emitting radionuclides; monthly analyses for radionuclide and stable element concentration in each of the listed compartments; and intercompartment exchange rate studies. Radionuclide release data accumulated since April 1971 is compared with monthly measurements of radionuclide concentration in the Bay. It is found that the amounts released have little effect on field concentrations. Exchange study programs now being carried out in the discharge canal and the laboratory are discussed. The nature and status of a proposed transport model for the Bay is described.

850. Held, E.E. 1960. Land crabs and fission products at Eniwetok Atoll. Pacific Science 14(1):18-27.

Periodic determinations of radioactivity in land crabs from Belle Island, Eniwetok Atoll, were made over a period of nearly two years following the 1954 atomic testing program. Radioactivity in exoskeleton was found to be due almost entirely to radiostrontium and the Y-90 daughter of Sr-90 and remained at a nearly constant level, excepting physical decay. An estimate of contributions of radiostrontium from previous tests to a crab skeleton at Belle Island is given. Long-lived fission products in muscle tissue consisted of 84% Cs-137, 10% Sr-90 + Y-90, and 1% Ce-144 + Pr-144. A possible association between the availability of cesium and rainfall is suggested. During the first 150 days following a nuclear detonation the rate of decline of radioactivity in organisms on an atoll island may be considered to approximate the rate of decay of mixed fission products. In so far as the long-lived fission products strontium, cesium, and cerium are concerned there appears to be a strontium-cesium food cycle in the lagoon.

851. Held, E.E. 1963. Qualitative distribution of radionuclides at Rongelap Atoll. In Schultz, V., and A.W. Klement, Jr. (eds.). Radioecology. Reinhold Publ. Corp., New York: 167-169.

The qualitative distribution of radionuclides at Rongelap Atoll as determined approximately five years after contamination by fallout from a thermonuclear device indicates distinct differences between the terrestrial and marine environments. The levels of radioactivity are low, the concentrations being less than the maximum permissible concentration for radionuclides in food or drinking water of man. Of the wide spectrum of radionuclides concentrated in the surface layers of the soil, strontium-90, antimony-125, and cesium-137 are the principal nuclides entering into the soil solution. The principal nuclides in the land plants and plant-eating animals such as coconut crabs and the indigenous rats are cesium-137 and, to a lesser degree, strontium-90. Bottom sediments contain mainly strontium-90 and europium-155. The radionuclides in the lagoon water have not been detected but are probably present in minute amounts. Planktonic organisms contain traces of manganese-54, cobalt-57, 60, zinc-65, zirconium-95, ruthenium-106 and cerium-144. The principal nuclide found in the marine algae is cerium-144. In the marine invertebrates cobalt-60 and zinc-65 occur most commonly. Corals and coralline algae contain some strontium-90, while the fish and sea birds are found to contain mostly zinc-65. The presence of zinc-65, cesium-137, and strontium-90 in the body of the natives reflects a diet of both marine and terrestrial origin.

852. Held, E.E. 1963. Some aspects of the biology of zirconium-95. In Schultz, V., and A.W. Klement, Jr. (eds.). Radioecology. Reinhold Publ. Corp., New York: 577-579.

The biological half-life of zirconium-95 is much longer than its 65-day physical half-life. Uptake from environmental contamination is mainly by the oral route in animals and probably by foliar contamination in plants, and the fraction absorbed is very small. Surface contamination of plants is probably the main source to mammals. In aquatic systems adsorption and the ingestion of particulate matter are of major importance. Due to its availability, half-life, and ability to form complexes and colloids, zirconium-95 should be particularly useful as a tracer in biological studies of aquatic systems.

853. Held, E.E. 1971. Fallout radionuclides in Pacific ocean tuna. Available from Nat. Tech. Inf. Ser., Springfield, Va. 22151 as Rept. NVO-269-13:1-16.

Fe-55 is the most abundant fallout radionuclide in many marine organisms. Tuna obtained in 1968-9 from a Japanese fishery and from the vicinity of Bikini Atoll were analyzed for Fe-55, stable Fe, Cs-137, and Co-60. Fe-55 in the dark muscle and in the liver of a single fish was about the same and was about 10-fold greater than in light muscle. The results for the dark muscle showed a wide range (Fe-55, 3.3-1600 pCi/g dry weight; stable Fe, 49-500 mg/kg; specific activity, 0.02-8.6 nCi Fe-55/mg Fe). There was no correlation of Fe-55 with species, fish size, or date of catch. The Fe-55 of most fish caught at all locations was in the low range; however, the average was higher in fish north of the equator. Cs-137 averaged nearly the same in light and dark muscle (0.15 pCi/g dry weight). Co-60 was found only in the dark muscle and liver tissues of fish caught off Bikini Atoll (0.08-5.0 pCi/g dry weight).

854. Hendrick, R.D., and T.R. Everett. 1965. Toxicity to the Louisiana red crawfish of some pesticides used in rice culture. Jour. Econ. Entomol. 58:958-961.

Juveniles of *Procambarus clarkii*, a lobster-like crustacean, weighing 0.1-2.5 g were exposed to dilutions of aldrin, methyl mercury dicyandiamide, and methyl parathion in laboratory tests to determine their response to these pesticides. The 5-day median tolerance limit (TLm) for aldrin, methyl mercury dicyandiamide, and methyl parathion was 38 μg/l, 83 μg/l, and < 0.010 μg/l respectively. Adult crawfish were found to have a 5-day TLm of 600 μg/l for aldrin. Adult crawfish tested in field cages were not measurably affected by aldrin seed treatments at the rates of 22 and 45 g/kg toxicant of rice seed alone or in combination with 8 ml of a 2.2% solution of methyl mercury decyandiamide kg seed.

855. Hernandorena, A. 1974. Effects of salinity on nutritional requirements of *Artemia salina*. Biol. Bull. 146:238-248.

At 24°/oo salinity the energy requirement of *Artemia* is met by starch or lecithin. With increasing salinity, the energetic nutrient requirement decreases and the albumin requirement increases; morphogenic changes become evident. The possible significance of salinity induced modifications in energetic nutrient and albumin requirements is discussed.

856. Hill, C.W., and P.O. Fromm. 1968. Response of the interrenal gland of rainbow trout (*Salmo gairdneri*) to stress. Gen. Compar. Endocrinology 11(1):69-77.

Exposure of trout to environmental hexavalent chromium (0.02 and 0.2 mg/liter of water) for one week caused a significant elevation of plasma cortisol. Fish exposed to these concentrations for 2 and 3 weeks had plasma levels similar to those of controls.

857. Hill, J.M., and G.R. Helz. 1973. Copper and zinc in estuarine waters near a coal-fired electric power plant-correlation with oyster greening. Environmental Letters 5(3):165-174.

Oysters in waters around the Chalk Point Power Plant, Maryland, accumulate Cu, especially in the summer; however, it appears that the power plant itself is not the primary Cu source. A series of water samples collected in the summer 1972 and analyzed for Cu and Zn reveal that the concentration of both metals increased during the summer, that this increase was greatest in bottom waters, and that waters near the power plant contained more Cu than those elsewhere. Horizontal distribution of Cu in the water agrees with the previously observed horizontal distribution of Cu accumulation in oysters. The maximum Cu concentration observed in the water was 31.5 µg/l; maximum Zn was 50.4 µg/l.

858. Hill, L.G., and D.R. Carlson. 1970. Resistance of the plains killifish Fundulus kansae (Cyprinodontidae) to combined stresses of temperature and salinity. Proc. Oklahoma Acad. Sci. 50:75-78.

Transference experiments were used to evaluate the resistance of F. kansae to the combined stresses of temperature and salinity. Salinities ranging from 0.5% to 1.5% provided maximum protection against death from heat shock. Higher salinities presumably minimize survival when exposed to heat shock. As temperatures decreased, optimum salinities for survival decreased. Young-of-year fish manifested greater resistance to test factors than did adults. The habitat preference of a particular life history-form appeared to correlate with its relative resistance to stresses of temperature and salinity.

859. Hiller, J.M., and A. Perlmutter. 1971. Effect of zinc on viral-host interactions in a rainbow trout cell line, RTG-2. Water Research 5(9):703-710.

A study was undertaken to determine effects of zinc, in virus-host interactions, in the rainbow trout cell line, RTG-2. Titers of infectious pancreatic necrosis virus showed a significant enhancement, when cultured in the presence of 10 mg/l zinc. Average enhancement equalled an increase in titer of 70%. At a concentration of 7.5 mg/l zinc, no effect was observed. Treatment of cell monolayers with 10 mg/l zinc prior to inoculation with virus was sufficient to evoke the enhancement response. A mechanism of action is suggested in which zinc reduces the net negative charge on, either or both, the cellular or viral surfaces. This, in turn, reduces the electrostatic barrier between virus and cell and so enhances the adsorption of virus to the cell surface. It is proposed that since metallic cations can increase infectivity of disease-causing organisms such as viruses, the studies to determine biologically safe concentrations of these cations should include experiments on their interactions with virus-host systems.

860. Hiyama, Y., and R. Ichikawa. 1953. The influence of various types of tags and lead injection rate upon the mortality rate of fish. Bull. Japan. Soc. Sci. Fish. 19:376-381.

By injection of Pb acetate a passage of time can be recorded upon the layer of scales and other hard tissues of fishes. In aquarium experiments Pb acetate injection (0.1 cc 0.1% Pb acetate/10 g) had no influence on the mortality rate of goby (Acanthogobius flavimanus).

861. Hiyama, Y., and J. M. Khan. 1964. On the concentration factors of radioactive I, Co, Fe and Ru in marine organisms. Records of Oceanographic Works in Japan 7(2):79-106.

Studies on uptake and retention of iodine, cobalt, iron and ruthenium using radioactive tracers were conducted. Factors which influenced uptake were demonstrated including temperature, seasonal variation, size and/or age of organisms, light, amount of co-existing stable elements and physicochemical state. Distribution of nuclides in fish organs were compared and ascertained by ingestion and injection methods. I-131 and Co-60 data showed similarity in those two methods of administration but Fe-50 and Ru-106 were not comparable.

862. Hiyama, Y., and M. Shimizu. 1964. On the concentration factors of radioactive Cs, Sr, Cd, Zn, and Ce in marine organisms. Records of Oceanographic Works in Japan 7(2):43-77.

Concentrations of Cs-134, Sr-89, Cd-115m, Zn-65 and Ce-144 from seawater are reported for selected species of marine teleosts, echinoderms, crustaceans, molluscs and algae. With Cs, all species reached equilibrium within 10-20 days, except that fish muscle continued to accumulate after 20 days. Concentration factors for Cs and time in days to reach 50% equilibrium were lowest for algae (CF 1.2-2.0; 1 day) and highest for crustacean soft tissue (CF 15; 4 days). Factors affecting accumulation of Cs-134 include concentration of stable Cs, presence of chelating agents, water temperature, and stage of growth of organism.

Concentration factors for Sr and time to reach 50% equilibrium were highest for algae (5.3-6.7; 1 day) and crustacean exoskeleton (15 and 4 days) and lowest for echinoderm (<0.9; 1 day). Hard tissues of fish such as scales have retained Sr for comparatively lengthy periods. With Cd, green algae reached equilibrium after 15 days, and suggests that Cd turnover in algae is slower than Cs and Sr. Concentration factors were highest in viscera of fish (6-10), echinoderm (110), crustacean (>250), mollusc (52) and lowest in muscle and bony tissues. Stable Cd^{2+} added to the medium produced lower CF values. CF values for Zn were comparatively high: 290 for algae, 68 for mollusc viscera, >500 for crustacean viscera, >200 for echinoderm digestive tract, and up to 22 for fish (viscera highest, muscle lowest); time to reach 50% equilibrium ranged between 1 and 7 days. Addition of stable Zn reduced Zn-65 accumulation with Ce, CF values were >100 for algae, >40 in mollusc viscera and 5 for mollusc adductor muscle, 200 for crustacean viscera (25 for muscle, 2 for exoskeleton), >250 in echinoderm digestive tract (2.5 in gonad) and >70 in fish gill (0.3 in fish muscle); chelating agents reduced CF values of Ce in every instance.

863. Hobden. D.J. 1967. Iron metabolism in Mytilus edulis. I. Variation in total content and distribution. Jour. Mar. Biol. Assn. U.K. 47:597-606.

The iron content of fresh mussels from Southampton is usually 20-40 μg/g wet weight after animals have eliminated their gut contents. In the spring some animals have much higher iron contents, sometimes in excess of 100 μg/g. Prolonged starvation in sea water of low iron content will not reduce the mean iron content of the animals below 20-25 μg/g. This represents a permanent store. Higher values are produced by a temporary store that is lost rapidly on starvation. The highest iron concentrations are usually in the digestive gland, which contains the major part of the temporary store, much of which can be regarded as particles being subjected to the digestive processes. Only iron in the temporary store could be demonstrated by histochemical techniques.

864. Hobden, D.J. 1969. Aspects of iron metabolism in a freshwater mussel. Canad. Jour. Zool. 48:83-86.

Estimations of total iron content of tissues of Elliptio confirm that this animal concentrates iron. During starvation, tissue mass decreases more than total iron and an apparent increase in iron content results. Most iron is contained in the viscera and mantle, while muscular tissue contains least.

Fe-59 injected into visceral mass was rapidly translocated to gills and mantle where much of it accumulated in tissue that acted as a 'kidney of accumulation'. The Fe-59 did not become fully incorporated into the physiological iron pool in 10 days, nor was it rapidly excreted. There is little metabolic turnover of elemental iron. This iron store is much greater than needed in known enzyme systems. It may indicate hyperactivity of an uptake mechanism or the lack of an adequate excretory mechanism.

865. Hodge, V.F., T.R. Folsom, and D.R. Young. 1973. Retention of fall-out constituents in upper layers of the Pacific Ocean as estimated from studies of a tuna population In Radioactive Contamination of the Marine Environment, Int. Atom. Ener. Agen., Vienna, Austria: 263-276.

Repeated measurements of cobalt-60, zinc-65, manganese-54, caesium-137, silver-110m, silver-108m, and plutonium-239 in several organs of albacore tuna suggest that the upper layers of the north Pacific Ocean can retain large fractions of several species of trace elements for periods of a decade or more. For example, caesium-137 concentrations in the livers and muscle tissues of North Pacific albacore caught from 1965-1971 decreased to half in about 10 years. In comparison, the reported rate of input from fall-out during this period decreased more rapidly, closer to half in one year. This suggests a strong retention of caesium-137 in the upper water masses which are accessible to the fish. It is of interest to note that long environmental persistences in the upper oceanic layers are also indicated for some other nuclides that are much more highly accumulated by organisms than is caesium. For example, cobalt-60 and silver-108m concentrations in albacore liver tissues fell to half during this period in 2.6 and 7.1 years respectively. Plutonium-239 concentrations in the livers decreased to half in about 3.5 years. The attenuation rate of zinc-65 was discontinuous between 1965 and 1968. This fact, along with observation of comparatively high ratios of zinc-65 to cobalt-60 in tunas of the southern hemisphere following 1968, suggests that new large weapons were tested that gave off relatively large amounts of zinc-65.

866. Hoffman, F.L., V.F. Hodge, and T.R. Folsom. 1974. Polonium radioactivity in certain mid-water fish of the eastern temporal Pacific. Health Physics 26:65-70.

Natural radioactive Po-210 activities of nine food organisms of tunas were determined. These measurements included individual organ analysis in many instances for making comparisons with recently reported concentrations in the visceral organs of albacore. Of these samples, the highest Po-210 activity (61 pCi/g wet) was found on the viscera of a surface-living saury (fish). However, the average concentration in the nine food organisms (2.1 pCi/g wet) was significantly the same as the whole body values (1.5 pCi/g wet) observed in albacore.

867. Hoggins, F.E., and R.R. Brooks. 1973. Natural dispersion of mercury from Puhipuhi, Northland, New Zealand. New Zealand Jour. Marine Freshwat. Res. 7(1&2):125-132.

Mercury content of sediments and water in the Wairua River, Northland, and of molluscs from the river's estuary was determined to establish the extent of natural dispersion of mercury from deposits at the river's source at Puhipuhi. Mercury content per gram wet weight of cockles, Chione stutchburyi (0.032 mg/kg); rock oysters, Crassostrea glomerata (0.081 mg/kg); pipi, Paphies australe (0.019 mg/kg); and green-lipped mussels, *Perna canaliculus* (0.017 mg/kg) was compared with that of specimens of the same species from other areas where presumably only background concentrations exist. Mercury could be detected in sediments at least 35 km from the deposits, but in water only up to about 8 km. Normal background levels were established for the soft parts and individual organs of the 4 species of molluscs investigated. Of the molluscs found in the estuary, only *C. glomerata* had anomalous amounts of mercury, but the significance of this is unknown. Mercury levels of all molluscs were well below the generally accepted safety level of 0.5 mg/kg for fish for human consumption.

868. Hoque, E., and L. Oglesby. 1972. Further observations on salt balance in the sipunculid worm *Themiste dyscritum*. Comp. Biochem. Physiol. 42(4A):915-926.

Osmotic and ionic concentrations of centrifuged coelomic fluids of *T. dyscritum* were measured in worms adapted to a salinity range from 41 to 101% of normal seawater. *T. dyscritum* is an osmotic conformer over this entire salinity range, and is iso-ionic with respect to Na$^+$.

There is an apparently greater concentration of K$^+$ in coelomic fluid than in medium; this may result from release of intracellular fluids after cellular-damage during sampling. Worms freshly collected are iso-ionic with respect to Cl$^-$, but coelomic fluids of worms maintained in high salinities became hypo-ionic to the medium after a few days in the laboratory. Worms in low salinities in the laboratory are also hypo-ionic with respect to Cl$^-$. All sipunculids so far studied are probably osmoconformers with limited powers of ion regulation at any salinity.

869. Hori, R., and T. Kohno. 1974. On the content of sodium and potassium of the unfertilized egg of the Medaka, *Oryzias latipes* and its changes accompanying fertilization. Protoplasma 80:149-153.

The content of Na and K of medaka eggs was estimated by flame-photometry and activation analysis. In the unfertilized fish egg, the concentration of Na is lower than that of K, being approximately 70% of K. When the egg is fertilized, the amount of Na increases, while the amount of K decreases. The ratio K/Na is changed from 1.4 to 0.6 upon fertilization.

870. Hori, R., and T. Yoshida. 1973. On the magnesium content in sea urchin eggs and its changes accompanying fertilization. Protoplasma 77:137-140.

The content of total and bound magnesium of the eggs of Pseudocentrotus depressus and Hemicentrotus pulcherrimus was estimated by atomic absorption. Total magnesium was almost equal (0.128 μg/μg PO_4) in both species and did not change upon fertilization. Bound magnesium decreased in 15 min after fertilization and recovered to the original value in another 15 min.

871. Horne, A.J., and C.R. Goldman. 1974. Suppression of nitrogen fixation by blue-green algae in a eutrophic lake with trace additions of copper. Science 183:409-411.

Nitrogen fixation by blue-green algae in highly eutrophic Clear Lake, California, was severely inhibited by trace amounts of copper. The chelation capacity of the lake is probably saturated by indigenous copper. Additions were only 1/200 of those normally used in algal control. Since nitrogen fixation provides half of the lake's annual nitrogen budget, economical eutrophication control appears possible.

872. Hsiao, S.C. 1963. The radioecology of calcium. In Schultz, V., and A.W. Klement, Jr. (eds.). Radioecology. Reinhold Publ. Corp., New York: 525-532.

The use of calcium-45 in sea urchin has shown that there is an interchange of Ca between unfertilized eggs and the environment, that fertilized eggs accumulate Ca as they develop into plutei, and that sources of Ca seem to be the ambient seawater while Ca in food is not as important. In the process of calcium uptake the cortical region of the unfertilized egg, zygote, or blastomeres is the first station for accumulation. With increasing development calcium is transported by the processes of gastrulation and primary mesenchyme formation to the interior of the embryos where later mesenchyme cells transmit calcium to spicules. Temperature exerts a definite influence on uptake of calcium by sea urchin embryos: the optimum temperature for ionic uptake among subtropic sea urchins in the Mid-Pacific is about 30°C. At 10°C, uptake of calcium is blocked. Sea urchin embryos in this region can recover their normal rate of calcium uptake if interference due to lowering of ambient temperature does not exceed two days. Embryos of sea urchins can withstand an acute x-ray dose of up to 1,200 roentgens without any significant difference in calcium uptake from controls. An acute dose of about 19,000 r reduces uptake of calcium to one-half of control values.

873. Huckabee, J.W., and B.G. Blaylock. 1972. Transfer of mercury and cadmium from terrestrial to aquatic ecosystems. In

Metal Ions in Biological Systems, S.K. Dhar (ed.), Plenum Publishing Corp., New York: 125-160.

Plants from the Great Smoky Mountains National Park (GSMNP), a putative low background area (i.e., little or no mercury pollution) showed no concentrations exceeding 0.2 mg/kg (air dried weight) with mosses generally having higher concentrations than vascular plants. Cadmium concentrations were as high as 0.4 mg/kg (oven dried weight) in moss, with vascular plants always having lower concentrations.

Once the background levels of mercury in environmental samples for a region are known, the amount of mercury input via pollution can be deduced. Perhaps no source of regional mercury pollution is more important than the burning of mercury-containing coal. Coal fly ash collected as it settled in the environment at Oak Ridge National Laboratory (ORNL) contained 0.98 mg/kg mercury. Samples of this fly ash were tagged with radioactive mercury and employed in cycling experiments in laboratory microcosms and natural field plots. Mercury from fly ash was shown to be leached from the particles and rendered available for biological uptake. Although the Hg-203 tagged fly ash was applied to the terrestrial portion of the microcosms, Hg-203 slowly accumulated in sediments, snails, and fish.

The transfer rate of mercury and cadmium from terrestrial to aquatic ecosystems is dependent upon residence time in terrestrial compartments. Terrestrial cycling of inorganic mercury and cadmium was investigated by tagging field plots with soluble Hg-203 and Cd-109. Four months after application, vegetation contained four times more cadmium than mercury (based on percent of total input). Most (64%) of the remaining mercury was found in soil, while most (59%) of the remaining cadmium was found in litter. This data indicates that inorganic mercury is lost more readily from vegetation than cadmium.

The Great Smoky Mountains provide an opportunity to determine the background levels of trace metals in aquatic organisms, since several large watersheds are maintained in an undeveloped state in the higher elevations of the GSMNP. Geological and meterological considerations indicated that biota from these remote areas of the park would contain low concentrations of mercury. Fish of five species were collected from three of the larger streams and were found to contain a mean of 0.04 mg/kg mercury. There was no significant difference in mercury content in or among species from all three streams, nor was there any relationship of mercury concentration with fish weight. No differences in mercury concentrations were noted with fish analyzed whole, with gastrointestinal tract removed, and axial musculature.

The transport of mercury in oligotrophic streams such as those in GSMNP was studied at ORNL by tagging experiments with $CH_3{}^{203}HgCl$ and

$^{197}Hg(NO_3)_2$. Mercury-203 from methylmercury was shown to be cycled more slowly than ^{197}Hg from $^{197}Hg(NO_3)_2$. The elimination rate of ^{203}Hg from merhylmercury was twice as long as that of ^{197}Hg from $^{197}Hg(NO_3)_2$ in periphyton, and five to six times as long in snails and fish. However, both mercurials were retained in the sediments for comparable lengths of time. About 80% of the total activity from methylmercury was retained in the first 100 m of the stream, while about 75% of the activity from mercuric nitrate was retained in the first 100 m. Twenty-five percent of the ^{197}Hg from $^{197}Hg(NO_3)_2$ detected in the stream water was bound on suspended particles, while 4% of the ^{203}Hg from methylmercury was bound on the suspended particles.

Fish concentrated ^{203}Hg from methylmercury higher than any of the other biota, but they concentrated ^{197}Hg from $^{197}Hg(NO_3)_2$ less than did the other biota.

A similar stream tag experiment with cadmium revealed that ^{109}Cd from $^{109}CdCl_2$ is less mobile in the stream than mercury, since 95% of the total ^{109}Cd added was retained in the first 100 m. Twenty percent of the ^{109}Cd in the water was found on the suspended particles. As was the case with mercury, cadmium concentration in sediments was highly variable, due to stream turbulence and sediment distribution patterns.

The cadmium elimination rate of periphyton followed an exponential function, but snails and fish showed a net uptake in cadmium for about one week post-tag after which they showed net elimination. After 40 days, the fish had a higher concentration of cadmium than the other biota and remained higher for the duration of the experiment (85 days). Cadmium is thus shown to bioaccumulate in fish, with the liver-kidneys-intestines containing the highest percent of the body burden. Cadmium appears to be generally less mobile in the environment than mercury, although concentration factors of cadmium by aquatic animals are much lower than for methylmercury.

In aquatic environments, organisms acquire body burdens of heavy metals directly from the water via the gills and the food chain. The relative importance of these two routes of uptake has not been adequately assessed. The food chain green algae - detritus → blood worm → mosquito fish → largemouth bass is being studied using ^{203}Hg tracer. Preliminary results indicate that ^{203}Hg from methylmercury acquired via gills or food has a very long biological half-life in largemouth bass (> 1000 days) compared to mosquito fish (55 days). The efficiency of transfer of inorganic mercury from mosquito fish to largemouth bass was higher (40%) than for blood worm to mosquito fish (12%). The blood worm assimilated 60% of the inorganic mercury contained in the algae-detritus, it appears that food chain uptake can account for a significant percent of the mercury body burden in fish.

874. Huckabee, J.W., B.G. Blaylock, and N.A. Griffith. 1972. Mercury: Behavior of methyl amd nitrate forms in natural stream ecosystems. Oak Ridge National Lab. Environ. Sci. Div., Prepubl. Copy: 1-9.

Studies on 100 m sections of two small streams with radioactive mercury compounds and fluorescein dye showed that the rate of transport of methylmercuric chloride and mercuric nitrate in oligotrophic streams is similar. Water, fish, snails, watercress, periphyton and sediments were collected. Biotic uptake of the two forms of mercury differs following an acute input. The decreasing order for uptake of methylmercury was as follows: fish > snails > periphyton > macrophytes > sediments. The uptake of mercuric nitrate was snails > periphyton, macrophytes, sediments > fish.

875. Huggett, R.J., M.E. Bender, and H.D. Slone. 1973. Utilizing metal concentration relationships in the eastern oyster (Crassostrea virginica) to detect heavy metal pollution. Water Research 7:451-460.

The distribution of whole oyster Cu, Cd, and Zn with respect to salinity regimes in Chesapeake Bay, Md., allows prediction of areas that would be most affected by unnatural additions of these metals. A source in the low salinity areas would be potentially more dangerous to oysters and to those that consume them than one in high salinity. It was not possible to establish a single concentration suitable for an action level for Cd, Cu, or Zn in oysters which will definitely indicate pollution sources. A working model is presented for the Chesapeake Bay region.

876. Hunn, J.B. 1972. Blood chemistry values for some fishes of the upper Mississippi River. Jour. Minnesota Acad. Sci. 38(1): 19-21.

Plasma concentrations of Na, K, Ca, Mg, chloride, inorganic phosphate, glucose, lactic acid and total CO_2 and whole blood pH and hematocrit were determined for nine species of fish from the upper Mississippi River area. Most values fell within the ranges published for other species of freshwater fishes, except that plasma concentrations of K and chloride in sexually mature walleye pike were low. The chloride was compensated for by a high plasma total CO_2.

877. Hussain, M., and E.L. Bleiler. 1973. Mercury in Australian oysters. Marine Pollution Bull. 4(3):44.

Oysters (Crassostrea commercialis) destined for human consumption in Sydney are alleged to be contaminated with Hg. Analyses performed by the New South Wales Department of Health show that they contain no more Hg than oysters far from sources of pollution. Mercury concentration in oysters from nonindustrial areas was in the range of 0.003-0.017 mg Hg/kg wet wt whereas oysters from industrial areas indicated a range of 0.006-0.016 mg Hg/kg wet.

878. Ikeda, Y., H. Ozaki, and K. Uematsu. 1972. Serum iron level and total iron binding capacity in culture fish. Jour. Tokyo Univ. Fish. 59(1):43-53. (In Japanese.)

Serum iron levels, total iron binding capacities and iron saturation rates were determined in three species of artifically propagated fish: yellowtail (Seriola quinqueradiata), rainbow trout (Salmo irideus) and carp (Cyprinus carpio). In yellowtail, the serum iron level decreased when the fish meal contained 0 or 27.3 mg % dry weight of iron as iron succinate, but increased when diet contained 57.3 mg % of iron. In rainbow trout, serum iron level was the same in freshwater or in seawater. In carp, the level was lowest of the three species, being half that of yellowtail. Serum iron levels seemed to be related to the species, activity, diet, and water temperature. The total iron binding capacities were about the same for all three species. In yellowtail, iron saturation rate was the highest, but dropped with increased total iron binding capacity when fed iron-deficient diets. Between rainbow trout in freshwater and in seawater, slight differences were observed in total iron binding capacity and iron saturation rate. Carp fed an iron-deficient diet produced a rise in total iron binding capacity and a decline in iron saturation rate. These analyses are useful in diagnosis of nutritional deficiencies and some disease states. The increase in total iron binding capacity was attributed to a rise in transferrin present in the third fraction of serum protein in yellowtail fed the iron-deficient diet.

879. Ikeda, Y., H. Ozaki, and K. Uematsu. 1973. Effect of enriched diet with iron in culture of yellowtail. Jour. Tokyo Univ. Fish. 59(2):91-99. (In Japanese.)

Anemia in yellowtail (Seriola quinqueradiata) offerred diets of raw fish, a compound diet with 7.3 mg% of iron added, and a compound diet with 57.3 mg% of iron added were studied. The decreasing orders of body weight, erythrocyte count, hemoglobin level, color index and serum protein level after feeding of about 4 months, were: raw fish group > diet with 57.3 mg% of iron > diet with 7.3 mg% of iron. Decreasing weights of liver, kidney, spleen and heart were: 7.3 mg% > 57.3 mg% > raw fish group; however, effect of iron enrichment was not observed on digestive organs. Serum iron level was highest in the 57.3 mg% diet, and lowest in the 7.3 mg% of iron diet. Absorption of Fe-59 was highest in the 7.3 mg% iron diet and lowest in the 57.3 mg% group. Authors conclude that iron should be added to the compound diet in yellowtail culture at minimal levels of 57.3 mg%.

880. Imbamba, S.K. 1972. Mineral element content of some benthic marine algae of the Kenya coast. Botanica Marina 15(2):113-115.

Fourteen algal species (Ulva lactuca, U. rigida, U. reticulata, Chaetomorpha spp., C. crassa, Halimeda macroloba, Sargassum duplicatum, Turbinaria ornata, Padina commersonii, Stypopodium zonale, Galazaura subverticillata, Halymenia venusta, Laurencia papillosa, Gracilaria crassa) and one marine angiosperm (Cymodocea ciliata) collected from the Kenya coast were analyzed for N, P, K, Ca, and Mg. All the benthic marine algae analyzed exhibited considerable variation in the mineral element composition. They were also found to accumulate N, P, Ca, and Mg in greater concentrations than those found in the surrounding water. Accumulation ratios were highest in H. macroloba, P. commersonii, and G. subverticillata, all of which precipitate calcium carbonate as part of their cell wall.

881. Imlay, M.J. 1973. Effects of potassium on survival and distribution of freshwater mussels. Malacologia 12(1):97-113.

Potassium ions were lethal to 4 species of freshwater mussels: 11 mg/l of K^+ killed 90% of Actinonaias carinata, Lampsilis radiata siliquoidea and Fusconaia flava in 36-52 days of exposure; 7 mg/l of K^+ killed 100% of the latter 2 species in about 8 months. Amlema plicata was almost as sensitive as the other species. Similar K^+ concentrations occur naturally in many North American rivers. On the basis of the National Water Quality Network data on potassium concentrations and concentrations lethal to mussels in the laboratory, it was predicted that certain rivers would not have mussels and others would. Known distribution of mussels was generally correlated with the predicted locations. In one study the 6 rivers with more than 7 mg/l K^+ were devoid of mussels. Mussels were reported from 28 of 39 rivers with less than 4 mg/l K^+ but from only 2 out of 10 rivers with 4-7 mg/l K^+. The predicted maximum safe level for the continued existence of most freshwater mussels is 4-10 mg/l potassium. It is recommended that the concentration of potassium not be allowed to increase in mussel producing rivers if the concentration is above 4 mg/l.

881A. Ireland, M.P. 1974. Variations in the zinc, copper, manganese and lead content of Balanus balanoides in Cardigan Bay, Wales. Environmental Pollution 7:65-75.

A study was made of the concentration of zinc, copper, manganese and lead in barnacles taken at different times of the year but at two environmentally similar sites. Zinc occurred in the highest concentrations at all times of the year and at both sites. The highest concentration of all four metals was found at the southerly site. The lowest levels of zinc and copper at the northerly site were found in the summer months, and those of zinc, manganese and lead at the southerly site in March 1973. The distribution of metals at the two sites is discussed in relation to river flow rates and tidal flow, together with phytoplankton productivity. A possible effect on growth and fecundity is discussed.

882. Irukayama, K., M. Fujiki, F. Kai, and T. Kondo. 1962. Studies on the origin of the causative agent of Minamata disease. II. Comparison of the mercury compound in the shellfish from Minamata Bay with mercury compounds experimentally accumulated in the control shellfish. Kumamoto Medical Jour. 15 (1):1-12.

The mercury content in shellfish from Minamata Bay was about 100 mg/kg at the end of 1959. Afterwards it decreased gradually to 30 mg/kg in August, 1960, but in January of 1961 it showed a transitory increase to 50 mg/kg. In December, 1961 it was about 10 mg/kg. Mercury content in organs of control shellfish cultured in sea water containing inorganic mercury compounds was higher in gills than in other organs. Shellfish from Minamata Bay had a higher concentration in the nerve nodules. Animals fed fish and shellfish of Minamata Bay had a relatively higher mercury content in brain than in other organs. These results indicate that the mercury compound in shellfish from Minamata Bay might be the same as that accumulated in organs in cases of Minamata disease and that inorganic mercury compounds do not change to organic mercury compounds in the shellfish. From the results of digestion and steam distillation of the control shellfish cultured in the sea water containing various inorganic and organic mercury compounds, the organic mercury in the shellfish from Minamata Bay was considered to be an ethyl- or methylmercury compound.

883. Irukayama, K., T. Kondo, F. Kai, and M. Fujiki. 1961. Studies on the origin of the causative agent of Minamata disease. I. Organic mercury compound in the fish and shellfish from Minamata Bay. Kumamoto Medical Jour. 14(4):158-169.

Organic mercury in shellfish from Minamata Bay combines with protein, and no mercury could be extracted with water and organic solvents from the denatured protein. From alkali- and acid-hydrolysates of the shellfish, mercury was extracted with organic solvents. Animal experiments showed that the extracted mercury seems to be in an organic form. One-third of the mercury in the shellfish was in the filtrate from a digest which had been treated with 0.04% pepsin solution, pH 1.6, at 37°C for 24 hours. When the extracted protein and the fish from Minamata Bay were digested by the same method, most of the mercury in them was transferred into the digested fluid. From these results and animal experiments with the mercury extracted from the distillate with chloroform, the mercury compound is considered to be an organic mercury, having a boiling point over 100°C. The mercury compound in organs of human and animal cases appears to remain in an organic form.

884. Isaacs, J.D. 1972. Unstructured marine food webs and pollutant analogues. U.S. Dept. Comm., Fish. Bull. 70(3):1053-1059.

Cesium levels in several species of fish living in the Gulf of California differ substantially from levels of the same species living in the Salton Sea. Simplified trophic models of the two environments are developed by applying known information about the food chain in the Salton Sea to the more uncertain food web in the Gulf of California. Data on an unstructured food web matrix and equations are presented.

885. Ishibashi, M., T. Yamamoto, and T. Fujita. 1964. Cobalt content in seaweeds. Records of Oceanographic Works in Japan 7(2): 17-24.

The average cobalt content in 77 dried samples of seaweed composed of 38 species was 0.78 mg/kg, with values ranging from 0.11 (*Eisenea bicyclis*) to 4.54 (*Sargassum thunbergii*). There were considerable differences among species but no remarkable difference by seasons and by habitats.

In general, green seaweeds are high in cobalt and red seaweeds are low. Some brown seaweeds such as *Sargassum thunbergii*, *Padina arborescens*, and *Sargassum hemiphyllum* are high in cobalt; in contrast, the majority of brown seaweeds have lower cobalt values. Cobalt and iron content in limnetic weeds are higher than those in most seaweeds. Generally, seaweeds which have high iron also have high cobalt, and those which are low in iron are low in cobalt. The amount of cobalt appears not related to total ash content.

886. Ishikawa, M., M. Sumiya, and M. Saiki. 1973. Chemical behaviour of ^{106}Ru in seawater and uptake by marine organisms. In Radioactive Contamination of the Marine Environment, Int. Atom. Ener. Agen., Vienna, Austria: 359-367.

The physico-chemical behavior of prepared Ru-106 chloro- and nitrosyl chloro-complex species were investigated by filter paper electrophoresis using 0.1N $NaClO_4$ as a supporting electrolyte. Ru-106 chloro-complexes (III, IV) in a seawater system were fractionated physico-chemically into at least four "anionic", one "neutral" and one "cationic" species. The electrophoretic mobilities of fractionated Ru-106 species in seawater were found to be constant for the nitrosyl chloro-complexes (III) during the aging period from 2 to 240 h, but remarkable changes were observed on the electrophoretic patterns of Ru-106 chloro-complexes throughout the experimental periods. It appears, in both cases, that significant physicochemical changes take place within the initial stage after addition of Ru-106 complexes. Biological uptake experiments in clams, Meretrix lamarcki, were carried out with electrochromatographically fractionated ionic species of Ru-106 nitrosyl chloro-complexes. The gill and mid-gut gland (liver) showed high concentrations for all the fractionated species. Considerable differences of concentration factors (concentration ratio) of Ru by clams were observed in the anionic, cationic and neutral species, i.e., the concentration factor of the cationic fraction was 10 times higher than that of the other fractions. The order of the concentration factor was as follows: "cationic" > "neutral" $\geq$ "anionic" species.

887. Jackim, E. 1973. Influence of lead and other metals on fish delta-aminolevulinate dehydrase activity. Jour. Fish. Res. Bd. Canada 30(4):560-562.

Killifish, Fundulus heteroclitus, exposed to an initial concentration of 10 mg/l of Pb^{2+} as nitrate for 2 weeks in seawater showed no apparent ill effects or abnormal behavioral changes. Aminolevulinate dehydrase (ALA-D) activity of the lead nitrate treated fish decreased by 22% after exposure for 96 h and 18% at the end of 2 weeks. Fundulus exposed to 50 mg/l of Pb^{2+} and 0.02 mg/l of Hg^{2+} (initial concentrations) for 28 d manifested a marked inhibition of ALA-D in the early stages (both metals) and subsequent partial recovery of the Hg-treated fish. Fundulus were exposed to sublethal concentration of Cu^{2+} (1 mg/l), Cd^{2+} (10 mg/l), Pb^{2+} (10 mg/l), Zn^{2+} (10 mg/l) and Ag^{2+} (0.02 mg/l) for 4 and 14 d to determine the specificity of liver ALA-D inhibition. Pb produces the greatest decrease in activity while Cd, Zn and Ag were associated with increases. Lead produced an average 66% decrease in ALA-D activity in liver of winter flounder (Pseudopleuronectes americanus) when fish were exposed for 7 d to a 10 mg/l Pb^{2+} initial concentration. Kidney tissues from the same animals exhibited a 58% decrease in ALA-D activity over controls.

888. Janicki, R.H., and W.B. Kinter. 1971. DDT: Disrupted osmoregulatory events in the intestine of the eel *Anguilla rostrata* adapted to seawater. Science 173:1146-1148.

The drinking of seawater and absorption of water along with sodium across the intestinal epithelium are well-known osmoregulatory events in marine teleosts. The insecticide DDT impairs fluid absorption in intestinal sacs from eels adapted to seawater. Furthermore, this functional impairment has an enzymatic basis; DDT also inhibits the (Na^+ and K^+) activated, Mg^{2+}-dependent adenosine triphosphatase in homogenates of the intestinal mucosa. Thus, the extreme sensitivity of teleosts to organochlorine pollutants may involve the disruption of osmoregulatory transport mechanisms.

889. Janicki, R.H., and W.B. Kinter. 1971. DDT inhibits Na^+, K^+, Mg^{2+}-ATPase in the intestinal mucosae and gills of marine teleosts. Nature New Biology 233(39):148-149.

Between 1 and 50 mg/l of DDT inhibited Na^+, K^+, Mg^{2+}-ATPase activity in the intestinal mucosae of the winter flounder (*Pseudopleuronectes americanus*) and the king O'Norway (*Hemitripterus americanus*). In both species, measurable inhibition was recorded at 1 mg/l and inhibition was linear through to 50 mg/l. The Mg^{2+}-ATPase was unaffected by DDT, which inhibited Na^+, K^+, Mg^{2+}-ATPase in the intestinal mucosae of two other species. At a final DDT concentration of 50 mg/l, inhibition was 37% in the yellowtail flounder (*Limanda ferruginea*) and 35% in the longhorned sculpin (*Myoxocephalus octodecimspinosus*). In this study, the mackerel (*Scomber scombrus*) was the only species in which the intestinal mucosal Na^+, K^+, Mg^{2+}-ATPase activity was resistant to 50 mg/l of DDT. The effect of DDT on ATPase activity in the gill of *P. americanus* also was examined. Basal Na^+, K^+, Mg^{2+}-ATPase activity in the gills of three fish treated with DMF (N, N-dimethylformamide) alone was 0.95 ± 0.09 μmol Pi/mg protein x h; but in the gills of three fish treated with DMF and 50 mg/l DDT (1.4×10^{-4} M) it was 0.44 ± 0.01 μmol Pi/mg protein x h. The inhibition was 54% ($P < 0.01$). At 50 mg/l DDT also inhibited 25% of the Mg^{2+}-ATPase.

890. Jefferies, D.F., and C.J. Hewett. 1971. The accumulation and excretion of radioactive caesium by the plaice (*Pleuronectes platessa*) and the thornback ray (*Raia clavata*). Jour. Mar. Biol. Assn. U.K. 51:411-422.

The patterns of accumulation of caesium-134 by the organs and tissues of the plaice *Pleuronectes platessa* L., a marine teleost, and the thornback ray *Raia clavata* L., a marine elasmobranch, are described.

Estimates of the biological half-time and steady state concentrations in relation to sea water are derived, using a simple exponential model. The rate processes are examined again in an experiment to measure the rate of loss of caesium-134 from fish after a period of accumulation. The biological half-time, at 10°C, for caesium-134 in the muscle of plaice of 30 g weight is estimated to be 120-140 days, and in rays of 80 g weight 180-190 days. In all other tissues and organs examined the rate processes in the plaice are faster than in the ray. Estimates are made of the amount of caesium obtained from water and from food. It is concluded that the plaice obtains at least 50% of its caesium body burden from food and the ray probably more than 80%. Caesium is absorbed from water via the gut in both species, but whereas in the plaice this accounts for up to 50% of the intake from water, in the ray this is probably a much smaller pathway. Excretion in both species appears to be 90% extrarenal.

891. Jensen, A., B. Rystad, and S. Melson. 1974. Heavy metal tolerance of marine phytoplankton. I. The tolerance of three algal species to zinc in coastal seawater. Jour. Exper. Mar. Biol. Ecol. 15:145-157.

Tolerance levels to zinc ions of Skeletonema costatum, Thalasiosira pseudonana and Phaeodactylum tricornutum grown in dialysis culture in the local fjord water were studied. Declining relative growth rates were observed by addition of 50, 250 and 25,000 μg/l of zinc ions, respectively, for the three species of algae. Reduced final cell concentrations were found at lower zinc levels. At least for one species a significant increase in zinc uptake by the cells took place at zinc levels which did not seem to influence the growth and development of the alga. Two clones of Skeletonema costatum studied showed significant intraspecific differences regarding the tolerance to zinc pollution. Dialysis bioassay was found suitable for monitoring heavy metal pollution of aquatic recipients.

892. Jernelоev, A. 1972. Mercury--a case study of marine pollution. In The Changing Chemistry of the Oceans; Proc. 20th Nobel Symp., Aug. 16-20, 1971, Goteborg, Sweden: Wiley Interscience Div. John Wiley Sons, Inc.: 161-169.

Mercury in water exists almost entirely bound to suspended particles. Conversion of inorganic mercury to methyl mercury occurs in the surface layer of the sediment or on suspended organic particles in the water. A normal conversion rate in a Swedish lake is 0.1% per year of the total mercury present. In an oligotrophic system most energy and matter on one trophic level is transferred to the next. In a eutrophic system a larger proportion of the energy and matter on one trophic level goes to decomposition and a smaller proportion is transferred to the next trophic level. This means that a smaller proportion of the methyl mercury which accumulates in organisms will reach the top predators with the critical concentrations. If there is a high nutrient level in the aquatic system, the sedimentation rate will be high and thus tend to cover the mercury-rich sediment. Tidal areas and estuaries are favorable for high methylation rates, which could mean that the organisms there naturally contain high concentrations of mercury, but also that they are especially sensitive to further contamination. Due to the extreme oligotrophic characteristics of the high sea and lack of buffering sediment, marine top predators can increase their mercury levels as an effect of changes in the ecosystem other than an increase in the total mercury concentration.

893. Jerneloev, A., R. Hartung, P.B. Trost, and R.E. Bisque. 1972. Environmental dynamics of mercury. In Environmental Mercury Contamination, Hartung, R., and B.D. Dinman (eds.), Ann Arbor Science Publishers, Inc., Ann Arbor, Mich.: 167-201.

Most surface waters contain about 0.1 μg/l Hg, but this may be increased greatly by ultrafine particles in suspension. So far it has not been possible to differentiate clearly between inorganic and organic mercury in water samples from lakes and rivers. Hg solubility is decreased by the presence of sulfides and is increased by chloride and by humic acid. The methylation rate in sediments is generally well correlated with the microbiological activity. In one study, uptake by fish was found to depend on the presence of bacteria in the slime on the fish. Uptake by terrestrial plants appears to be relatively unimportant in terrestrial food chains, but the role of aquatic plants requires further study.

894. Jerneloev, A., and H. Lann. 1971. Mercury accumulation in food chains. Oikos 22(3):403-406.

The relation between methyl mercury concentrations in the liver and in muscle of fish indicates the relation between accumulation and excretion rates of methyl mercury. The total mercury content of benthic animals is of little interest when one calculates the rate of mercury transport from benthic animals to fish that feed on them. This is because the percentage of methyl mercury in the total mercury content of the benthos is generally low (much lower than the percentage in fish) and the total mercury content is very variable. The methyl mercury transportation from benthic fauna to bottom feeding fish is evidently small. By comparing the total mercury content of the three ecological subgroups of benthic animals, it seems possible to separate situations where release of mercury prevails from situations where it has ceased.

895. Johnels, A.G., T. Westermark, W. Berg, P.I. Persson, and B. Sjöstrand. 1967. Pike (Esox lucius L.) and some other aquatic organisms in Sweden as indicators of mercury contamination in the environment. Oikos 18:323-333.

Activation analysis of Hg content in axial musculature of pike (Esox lucius) has been used to estimate the level of Hg present in the water environment. The concentration factor from water to pike is of the order 3000 or more. The relation between Hg content and weight and age of fish specimens is discussed. By a graphical method, values for Hg content for specimens representing 1 kilogram of weight have been calculated for a number of localities and used for geographical comparison of Hg content of samples of pike from above and below localities, where emission of waste water containing Hg takes place. There are strong indications that Hg appears also as an airborne pollutant affecting the water environment. A number of sources of Hg contamination are discussed. It is concluded that in many areas human activities have raised mercury content of the environment far above the natural levels.

896. Jones, A.M., Y. Jones, and W.D.P. Stewart. 1972. Mercury in marine organisms of the Tay region. Nature 238(5360):164-165.

High levels of Hg were found in marine macroalgae and mollusks from the littoral zone at Broughty Ferry in the Firth of Tay (Scotland), but there was no detectable Hg in any samples north of Arbroath. Mean total Hg concentrations in algae and mollusks from the Tay region, distribution of Hg in Fucus vesiculosus and Mytilus edulis, and total Hg levels in eider ducks and grey seals are tabulated.

897. Jones, J.R.E. 1939. Antagonism between salts of the heavy and alkaline-earth metals in their toxic action on the tadpole of the toad, Bufo bufo bufo (L.). Jour. Exp. Biol. 16:313-333.

Survival curves are described for nitrate salts of Ni, Cu, Cd, Mg, Ca, Sr, and Ba for toad tadpoles. Survival curves for tadpoles in mixtures of equally toxic solutions of nickel nitrate and strontium nitrate indicate marked antagonistic action between these salts, the effect increasing with dilution. The survival curve for mixtures of the equally toxic solutions 0.03 copper nitrate and 0.40 N strontium nitrate apparently indicate antagonism over a part of the concentration range and synergism over the remainder. This is because a 0.03 N solution of copper nitrate increases in toxicity upon dilution, its toxicity reaching a maximum at approximately 0.0015 N. If the normality of the copper solution is below this critical value its mixture with an equally toxic strontium solution gives a normal antagonism curve. It is shown that salts of Ca, Mg and Ba also reduce toxicity of Cu solutions. The Sr concentration—Cu concentration—survival surfaces for Cu and Ca, Cu and Mg, and Cu and Ba are of similar type.

898. Jones, J.R.E. 1939. The relation between the electrolytic solution pressures of the metals and their toxicity to the stickleback (Gasterosteus aculeatus L.). Jour. Exp. Biol. 16:425-437.

Lethal concentration limits have been determined for H^+ and ions of 18 metals using the three-spined stickleback (Gasterosteus aculeatus L.) According to their lethal concentration limits on a mg/l basis their order of increasing toxicity is:

Sr Ca Na Ba Mg K Mn Co Cr Ni Au Zn Cd Pb Al Cu H Hg Ag.

On a molar concentration basis this is:

Na Ca Sr Mg Ba K Mn Co Cr Ni H Zn Al Au Cd Pb Cu Hg Ag.

All these ions, with the exception of the first six (the metals of the alkalis and alkaline earths), bring about the death of fish by precipitating the gill secretions, thus causing asphyxiation. Alkali and alkaline earth metals appear to enter the body and act as true internal poisons. The position of iron is uncertain. The toxicity of solutions of iron salts appears to be due, mainly if not entirely, to their acidity. On a mg/l or molar concentration basis there is a marked relationship between the toxicity of the metals and their solution pressures. The metals of very low solution pressure (Ag, Cu, etc.), i.e., those whose ions are most ready to part with their charges and enter into combination with other ions or compounds, are the most toxic as they precipitate the gill secretions and bring about asphyxiation with extreme rapidity. Metals of somewhat higher solution pressure (Zn, Pb, Cd) act in the same way but more slowly. Manganese, which of all the heavy metals has the highest solution pressure, takes effect very slowly and the ions of the alkali and alkaline earth metals, which have a high affinity for their charges, do not precipitate the gill secretions at all.

With ions other than alkali and alkaline earth metals, the reactions responsible for death of the fish are extrinsic; thus, their speed of action does not depend on penetrating power and the permeability factor does not enter. This is probably responsible for the good agreement observed between toxicity and affinity for electrical charges.

899. Jones, J.R.E. 1947. The reactions of *Pygosteus pungitius* L. to toxic solutions. Jour. Exp. Biol. 24:110-122.

An apparatus is described in which small fish (*Pygosteus pungitius* L.) are confined in a horizontal glass tube, half of which is filled with flowing tap water and half with flowing solution. Solution and water are very sharply differentiated, so that the concentration difference the fish encounter is known. The directions of flow can be rapidly reversed in order to check the result. The movements of the fish are recorded for 7-120 min., according to the degree of toxicity of the substance tested. A negative reaction is shown towards 1% ethyl alcohol, 1/10,000-1/5000 chloroform and 0.1-0.4% formalin (% HCHO). High concentrations of these substances may stupefy the fish so rapidly that a pseudo-positive reaction appears.

A sharp negative reaction is displayed towards 0.003-0.001 N mercuric chloride; at 0.0003 the reaction is delayed, at 0.0001 is indefinite, and at 0.00004 N solution, though of comparatively high toxicity, does not appear to be detected. Zinc sulphate appears to be detected and avoided at concentrations at least as low as 0.0003 N. This concentration is of comparatively low toxicity and may be exceeded in streams polluted from zinc mines. Copper sulphate is only detected and avoided at extremely high concentrations (0.1N). At 0.04 N the reaction is vague, and at 0.01-0.001 N the fish swim into the solution where they become stupefied and lie motionless, so that the reaction appears positive. Copper salts appear to impair or destroy the stickleback's ability to distinguish other toxic substances.

899A. Jones, M.B. 1973. Influence of salinity and temperature on the toxicity of mercury to marine and brackish water isopods (Crustacea). Estuarine and Coastal Marine Science 1:425-431.

Under optimum conditions of salinity (100% S.W.=34°/oo) and temperature (10°C) marine (*Idotea emarginata* and *Idotea neglecta*) and estuarine (*Faera nordmanni* and *Faera albifrons sensu stricto*) species of isopods can tolerate concentrations of one mg/l and 0.1 mg/l mercury (mercuric chloride) for 5 days without achieving 50% mortality. A decrease in salinity and an increase in temperature caused a dramatic increase in toxicity of mercury as evidenced by lower LC-50 values. These results indicate that species adapted to a fluctuating estuarine environment are more influenced by the extra stresses of heavy metal pollution than marine forms for which environmental variables are relatively more stable.

900. Kähler, H.H. 1970. On the influence of adaptation, temperature and salinity on heat and cold resistance of *Enchytraeus albidus* (Oligochaeta). Marine Biology 5:315-324.

This paper investigates the combined effects of temperature and salinity on resistance-adaptation to temperature in the oligochaete *Enchytraeus albidus*. This worm shows reasonable resistance-adaptation to both cold (-13.2°C) and heat (35.8°C). Acclimation to high salinity increases the degree of resistance to temperature extremes. The effect of salinity on heat-resistance, and especially on cold-resistance, decreases with rising adaptation-temperature. While a general effect of cations (Na, K, Ca, Mg) on temperature resistance does not exist, the influence of special ions depends upon ion concentration and adaptation-temperature; addition of Na, K, Ca, and Mg reduces cold-resistance in cold-acclimated (5°C) individuals, while, in warm-acclimated (23°C) specimens, cold tolerance increases after addition of K and Ca. Heat-resistance decreases in warm-acclimated worms after addition of Mg and Ca. Higher proportions of cations reduce thermal resistance in all cases. Over the salinity range which allows homeo-osmotic conditions (2 to 15^{o}/oo), *E. albidus* does not exhibit a constant resistance level (at least not to heat). The cryoprotective agent dimethylsulphoxide is highly effective both in cold and warm acclimated worms.

901. Kalnina, Z., and G. Polikarpov. 1969. Strontium-90 concentration factors of lake plankton, macrophytes, and substrates. Science 164(3887):1517-1519.

The ratio of concentration of strontium-90 in living and inert lake components to that in lake water (concentration factors) was determined for plankton, macrophytes, and substrates in eutrophic, mesotrophic-eutrophic, and dystrophic lakes. Concentration factors of strontium-90 in aquatic organisms and substrates are higher in a dystrophic lake than in the other types.

902. Kamps, L.R., R. Carr, and H. Miller. 1972. Total mercury-monomethylmercury content of several species of fish. Bull. Environ. Contamin. Toxicol. 8(5):273-279.

Data are presented on total mercury and monomethylmercury content in edible portions of five species of fish. Total mercury content ranged from 0.04 to 2.60 mg/kg. The proportion of methylmercury to total mercury ranged from 67 to 125%. Comparative data from the 36 samples analyzed show that mercury in edible portions of swordfish, tuna, northern pike, white bass, and perch is essentially all monomethylmercury.

903. Kaplan, H.M., and L. Yoh. 1961. Toxicity of copper for frogs. Herpetologica 20:131-135.

Frogs exposed continuously, over a range of environmental temperatures, to aqueous solutions of copper sulfate exceeding 10 mg/l are not apt to survive. The duration of life decreases with increasing concentration of the copper sulfate.

The small concentration of copper ordinarily existing in tap water has no measurable effect upon *Rana pipiens*.

904. Karbe, L. 1972. Marine hydroids as test organisms for assessing the toxicity of water pollutants, the effects of heavy metals on colonies of *Eirene viridula*. Marine Biology 12:316-328.

The colonial hydroid *Eirene viridula* (Thecata, Campanulidae) was cultured in natural sea water, and fed twice a week with larvae of *Artemia salina*. Upon changing the culture water 1 h after feeding, various dosages of zinc, lead, cadmium, copper or mercury were applied in order to assess the response of the polyps to pollutants. Test periods were restricted to 2 or 3 weeks during standard experiments, to 3 months during long-term experiments. Doses of 3 mg/l copper or 0.3 mg/l mercury led to tissue disintegration within a few hours. Low doses of heavy metals (3 to 10 mg/l Zn, 1 to 10 mg/l Pb, 0.3 to 10 mg/l Cd, 0.06 to 1 mg/l Cu, 0.003 to 0.1 mg/l Hg) caused morphological changes and tissue reorganization of hydranths. In addition to morphological effects, colony growth and reduction of hydranth number provide information on the severity of damage. Most processes were reversible after transfer into uncontaminated sea water. Irreversible damage resulted from experiments with mercury at doses as low as 0.02 mg/l Hg. In experiments with 3 mg/l Zn and 0.3 to 0.1 mg/l Cu, compensation (proliferation of new hydranths) were observed within the second week. In all cases, cadmium and mercury caused cumulative effects; 0.3 mg/l Cd or 0.01 to 0.003 mg/l Hg led to morphological changes only after at least 2 or 3 weeks. Threshold concentrations for acute effects of zinc, lead, cadmium, copper, and mercury are: 1.5 to 3 mg/l Zn, 1 to 3 mg/l Pb, 0.1 to 0.3 mg/l Cd, 0.03 to 0.06 mg/l Cu, and 0.001 to 0.003 mg/l Hg. In comparison to other marine organisms *E. viridula* represents a highly sensitive test organism. Because it can be cultivated rather easily, author recommends that this species be utilized in marine bioassays.

905. Karppanen, E., K. Henriksson. 1970. Mercury content of game birds in Finland. Nordisk Medicin 84(35):1097-1098.

The mercury content was studied of some gallinaceous and aquatic birds which are the objects of hunting. Birds which feed on aquatic animals have a markedly increased content of mercury as compared with terrestrial birds. This has become obvious after the prohibition of the use of alkyl mercury compounds for seed dressing. Although the limited use of these game birds as food does not imply that the elevated mercury content is an imminent threat to man, a continued survey of the situation is important.

906. Kazantzis, G. 1971. The poison chain for mercury in the environment. Inter. Jour. Environ. Studies 1:301-306.

The toxic effects of mercury in specific population groups have long been known, but mercury as a general environmental hazard has followed comparatively recent technological development. Contamination with both inorganic mercury and organic mercury compounds has resulted from industrial waste and from the use of the latter compounds as fungicides. Deposited eventually in rivers and lakes, this has led to raised levels of mercury in fish. Under appropriate conditions, methylation of mercury may occur in the natural environment, converting less toxic inorganic and aryl mercury compounds into the more toxic alkyl mercury form. In certain predominantly fish-eating populations this had led to an increase in the body burden for organic mercury, resulting in localized outbreaks of methyl mercury poisoning. Raised levels of mercury in eggs and bird tissues have resulted from feeding on mercury contaminated fish and on organomercury treated seed. In addition to the direct toxic action of mercury, limited evidence suggests that methyl mercury compounds may possibly exert mutagenic and teratogenic effects, at levels below those usually associated with poisoning.

907. Keckes, S., S.W. Fowler, and L.F. Small. 1972. Flux of different forms of ^{106}Ru through a marine zooplankter. Marine Biology 13:94-99.

The dynamics of accumulation and loss of different physicochemical forms of Ru-106 were measured in the euphausiid *Megancytiphanes norvegica*. The accumulation of Ru-106 was directly related to the concentration of the radioisotope in solution, as evidenced by similar concentration factors for euphausiids in the "low" and "high" activity Ru-106 chloride solutions. The chemical form of the radioisotope in solution had a pronounced effect on the uptake, with Ru-106 chloride fractions being accumulated at a faster rate than Ru-106 nitrosyl-nitrato complexes. Euphausiids lost Ru-106, previously accumulated from Ru-106 nitrosyl-nitrato forms. Also, in the case of the Ru-106 chloride complexes, the loss rate was inversely proportional to the time allowed for isotope accumultion. The process of molting greatly accelerated the loss of Ru-106 from euphausiids, with first molts shed during the loss phase accounting for 70 to 80% of the total Ru-106 body burden. When euphausiids accumulated Ru-106 from the food chain, the initial-loss rate was rapid due to large amounts of the radioisotope associated with fecal pellets; however, no relationship was found between loss rate and the number of food rations received. Molts from these individuals did not contain Ru-106, thus, loss from euphausiids obtaining this radioisotope through the food chain is mainly due to fecal pellet deposition and other excretion or exchange processes.

908. Keckes, S., and J.J. Miettinen. 1972. Mercury as a marine pollutant. In Ruivo, M. (ed.). Marine Pollution and Sea Life. Fishing Trading News (books) Ltd., London: 276-289.

Until recently man's activity did not contribute considerably to changes in the marine environment, but with the fast technological development in the last decades the direct or indirect disposal of various potentially harmful products and by-products into the seas and oceans became reality. Mercury and its compounds belong in this category and it is estimated that at present half of the annual input of mercury into seas and oceans (about 5,000 t) is the result of uncontrolled release from the industrial and agricultural use of mercury compounds. Locally, in Japan, the input of mercury into sea water and thereupon into edible organisms raised the content to a level which caused the death of more than 40 people. In Scandinavian countries strict regulations had to be applied to avoid similar tragedies.

The mercury concentration in sea water is very low, 0.03 to 0.27 μg/l, but due to mercury's high chemical reactivity and biological toxicity its increase has a strong deleterious effect on organisms. The biological transformation of relatively less toxic forms of mercury into those with very high toxicity and its bioaccumulation directly from sea water or through the food chains returns the mercury to man in a concentrated form, which apart from direct toxic effects can also have a genetic effect.

These aspects of mercury as a marine pollutant are reviewed and the present status of our knowledge concerning the biogeocycle of mercury and the impact on marine organisms, especially fish, are discussed.

909. Keckes, S., B. Ozretić, and M. Krajnović. 1968. Loss of Zn-65 in the mussel *Mytilus galloprovincialis*. Malacologia 7(1):1-6.

Loss of Zn-65 from soft tissues and shells of mussels was investigated under laboratory conditions. The rate of relative biological loss was higher in shell than in soft tissue and depended on the time exposed to sea water containing Zn-65, loss rate being higher after a short contact time. The presence of EDTA (50 mg/l) increased the loss of Zn-65. Rate of relative biological loss was not constant but initially more rapid, indicating multicompartmental zinc metabolism in *Mytilus*.

910. Keckes, S., B. Ozretić, and M. Krajnović. 1969. Metabolism of Zn-65 in mussels (*Mytilus galloprovincialis Lam.*). Uptake of Zn-65. Rapp. Comm. int. Mer Medit. 19(5):949-952.

The uptake of radiozinc in mussels is rapid but equilibrium is reached only after a long period. The uptake is about ten times higher for soft tissues than for shells; 0.01 to 50 mg EDTA per liter significantly depresses uptake of radiozinc with effect of EDTA dependent on concentration.

911. Keckes, S., Z. Pucar, and L. Marazović. 1967. Accumulation of electrodialytically separated physico-chemical forms of ^{106}Ru by mussels. Int. J. Oceanol. and Limnol 1(4):246-253.

Ru-106 nitrosyl-nitrato and chloro complexes were separated in sea water by electrodialysis through ion-exchange membranes, and biological uptake and loss experiments in mussels were made with separated fractions.

The metabolism of Ru-106 was found highly dependent not only on its chemical form but also on its physico-chemical form. The uptake of Ru-106 chloride fractions is faster than that of Ru-106 nitrosyl-nitrato fractions. Furthermore the uptake is higher in the soft tissues than in the shells of mussels. It seems that the binding of Ru-106 in the shells is not as firm as in the soft tissues.

912. Keffler, L.R. 1972. A study of the influence of calcium on the effects of DDT on fishes. Ph.D. Thesis: 1-131. Available from University Microfilms, 300 No. Zeeb Rd., Ann Arbor, Mich. 48106, as 73-1275.

The relationship between calcium deficiency and DDT poisoning in goldfish, *Carassius auratus*, and golden shiners, *Notemigonus crysoleucas*, were tested using 16 different combinations of calcium and DDT concentrations; three different salts were used as sources of Ca^{2+}. Fishes poisoned with DDT in the laboratory exhibited symptoms of calcium deficiency. Increasing the concentration of calcium ions in the water from 0 to 200 mg/l seemed to alleviate the DDT poisoning symptoms of fishes and decrease the death rate, provided that the DDT concentration did not exceed 20 μg/l. Goldfish were more responsive to treatment than golden shiners. Of the calcium salts used, calcium chloride was more effective than either calcium carbonate or calcium gluconate. Two possible conclusions to be drawn are that DDT is not simply a neurotoxin, and that the calcium differences, between hard and soft water may be sufficient to give a survival advantage to fish in the hard water regions of the country.

913. Kelso, J.R.M., and R. Frank. 1974. Organochlorine residues, mercury, copper and cadmium in yellow perch, white bass and smallmouth bass, Long Point Bay, Lake Erie. Trans. Amer. Fish. Soc. 103(3):577-581.

Three collections of yellow perch, white bass and smallmouth bass were made in May, July and late October for analyses of DDT, PCB, mercury, copper and cadmium. Fat content varied seasonally among collections, lowest in spring and highest in fall. DDT ranged from 0.09 to 0.27 μg/g and exhibited no seasonal changes. No difference among species existed for DDT in spite of differing fat content, but concentrations within a species increased with increasing fat and subsequently age. PCB's were up to 6.5 times greater than DDT levels. PCB residues, lowest in yellow perch and highest in white bass, did not vary with season but increased with increasing fat. Dieldrin was low and no trends relating to season or fat were apparent.

Only two specimens contained mercury residues above 0.5 μg/g. Mercury was apparently related to size and subsequently age. Copper was slightly higher in yellow perch, means ranged from 1.29 to 1.56 μg/g, but copper and cadmium were low in all species.

914. Kendall, M.W. 1972. Acute effects of administration of methyl mercuric chloride on tissues and enzyme activity in channel catfish (Ictalurus punctatus). Ph.D. Thesis: 1-101. Available from Office Water Res. Research as OWRR-A-038-KY (2).

In Kentucky and neighboring southeastern states, channel catfish are extensively cultured as a food crop. Acute exposure to methyl mercuric chloride causes enzyme and tissue alterations. The principal reaction of absorbed mercury is to bind thiols, forming mercury mercaptide. The ultimate effect of mercury and its compounds is based upon its ability to inhibit enzymes. In the channel catfish, a single intraperitoneal injection of 15 mg/kg methyl mercuric chloride caused deposition of mercury in liver, kidney, skeletal muscle, and gill. Marked pathology was evidenced by necrosis in the liver, necrosis of pancreatic tissue within portal venous walls, necrosis of renal tubular cells and marked thickening of renal glomerular basement membrane. The principal effects on enzymes were facilitation of acid phosphatase, alkaline phosphatase, and leucine aminopeptidase and inhibition of succinic dehydrogenase and oxygen consumption. A lower dosage of 1.5 mg/kg methyl mercuric chloride produced no structural alterations but did produce changes in enzyme activity. These alterations in tissues and enzyme activity are indicative of acute methyl mercuric chloride intoxication in the channel catfish.

915. Kevern, N.R., and S.A. Spigarelli. 1971. Effects of selected limnological factors on the accumulation of cesium-137 fallout by largemouth bass (Micropterus salmoides). Proc. Third Nat. Symp. Radioecology, U.S.A.E.C. Conf. 710501, 1:354-360.

Variation between Cs-137 concentrations in natural populations of largemouth bass in six southern Michigan lakes was studied. The lakes were selected to provide a wide range of limnological types ranging from very low to high specific conductance.

Mean Cs-137 concentrations of three-year-old bass collected from each lake during June 1969 were compared, and a multiple regression analysis was performed to determine the correlation between water chemistry parameters viz Na, K, Cs-137, total Cs, and specific conductance, and the accumulation of Cs-137 by bass. Simple correlation coefficients indicated inverse relationships between total Cs, Na, and specific conductance of lake water and Cs-137 activity of bass, with specific conductance providing the best linear fit.

Multiple regression analysis altered the relative importance of each water parameter and resulted in the deletion of Na and specific conductance from the model due to lack of significant addition to the multiple correlation coefficient.

916. Kihlstrom, J.E., and L. Hulth. 1972. The effect of phenylmercuric acetate upon the frequency of hatching of eggs from the zebrafish. Bull. Environ. Contamin. Toxicol. 7(2/3):111-114.

The effect of phenylmercuric acetate on frequency of hatching, and time required for development of eggs was investigated. Frequency of hatching was significantly higher in water containing 10 μg/l of phenylmercuric acetate than in the controls. At a concentration of 20 μg/l, the frequency of hatching was the same as in controls. All eggs failed to hatch at 50 μg/l. Most control eggs hatched about three days after fertilization. However, the frequency of eggs hatching up to and including the third day after fertilization is significantly higher in water containing 10 and 20 μg/l phenylmercuric acetate than in controls.

917. Kihlstrom, J.E., C. Lundberg, and L. Hulth. 1971. Number of eggs and young produced by zebrafishes (Brachydanio rerio, Ham.-

Buch.) spawning in water containing small amounts of phenylmercuric acetate. Environmental Research 4(4):355-359.

The number of eggs deposited and frequency of hatching have been studied in zebrafish before and after the addition of phenylmercuric acetate to water. The number of eggs deposited decreased in water containing 1 μg/l and higher of phenylmercuric acetate with a median effective dose (ED_{50}) of 2.2 μg/l. The frequency of hatching was diminished in eggs spawned in water containing 0.2 and 1 μg/l of phenylmercuric acetate.

918. Kilham, P. 1971. A hypothesis concerning silica and the freshwater planktonic diatoms. Limnology and Oceanography 16(1): 10-18.

The literature was examined to relate ambient silica concentrations to numerical dominance of specific freshwater planktonic diatoms. Mean silica concentrations (mg/liter) during dominance are *Stephanodiscus astraea*, 0.6; *Tabellaria flocculosa asterionelloides*, 0.9; *Asterionella formosa*, 1.7; *Melosira granulata*, 13.4. The concentration at time of dominance and patterns of diatom periodicity observed in many eutrophic lakes led to the hypothesis that declining ambient silica concentrations may influence the sequence of seasonal succession. When silica becomes depleted diatoms become scarce. It is suggested that some measure of "silica demand" could be used as an index of increasing eutrophication.

919. Kimura, K., and R. Ichikawa. 1969. Accumulation and retention of ingested ruthenium-106 by genuine goby. Bull. Japan. Soc. Sci. Fish. 35(5):434-440.

Accumulation and retention of Ru-106 by the marine fish, *Acanthogobius flavimanus*, was determined by feeding studies. The average uptake of Ru-106 following single oral administration was about 5% of the administered dose in either Ru/N or Ru/Cl form. Equilibrium was reached about 12 days later, with the body burden equal to about 20% of the average daily dose.

The concentration factor for goby over annelid worm was about 0.002, and hence, the transfer of Ru-106 through this kind of food chain was relatively small in comparison with direct uptake or exchange from the surrounding sea water.

920. Kinter, W.B., L.S. Merkens, R.H. Janicki, and A.M. Guarino. 1972. Studies on the mechanism of toxicity of DDT and polychlorinated

biphenyls (PCBs): Disruption of osmoregulation in marine fish. Environmental Health Perspectives, April, 1972:169-173.

Data on eels provides circumstantial evidence that disruption of osmoregulation is a primary toxic effect of DDT, i.e., the DDT levels in gut and gill of fatally-dosed fish were high enough to have affected osmoregulatory Na transport under in vitro conditions. The data also indicates that Mg-ATPase is less sensitive to DDT than Na, K-ATPase. It is also recognized that DDT may exert a primary toxic effect on the central nervous system; by 6 hr fatally-dosed eels were hyperactive and easily stimulated to convulsions by touch. Such symptoms, however, could be secondary to alterations to osmolarity of plasma and cerebrospinal fluid. Studies were conducted with PCB's and killifish using responses parameters of toxicity and osmoregulation. Toxicity data show that Aroclor 1221 was less toxic than DDT by a factor of about 100.

The osmolarity and Na concentration of serum consistently increased (toward sea water values) in fish exposed to lethal levels of either Aroclor 1221 or DDT. Aroclor and DDT levels selected for these serum-composition studies were potentially lethal to most fish, but low enough to have killed only some at the time (6 or 24 hr) samples were taken from survivors. With higher levels tested, most increases in serum osmolarity and Na were statistically significant. Serum osmolarity and K were elevated in all ethanol-treated controls; this elevation may have been due to the ethanol or to confinement of fish in experimental containers. Data show that in extreme cases, when blood was sampled before the fish died but after they had completely lost their righting ability and remained sideways, serum osmolarity and electrolyte concentrations were all increased above normal; osmolarity changes cannot always be accounted for by changes in measured electrolytes.

921. Kirchner, W.B., and S. Grabowski. 1972. Manganese in lacustrine ecosystems: A review. Water Resources Bulletin 8(6):1259-1264.

The literature of manganese in fresh water is reviewed. The major aspects of manganese occurrence discussed are: (1) sources, (2) geochemistry, (3) manganese-iron relationships, (4) effects on the fauna and flora, and (5) detection. There are three major ways that Mn enters natural waters. The basin's rocks may release Mn into solution by weathering. Industrial dumping is another pathway. Drainage from litter and soil is a lesser source. The chemical behavior of Mn is strongly affected both by oxidation-reduction potential and by pH. Solubility can also be influenced by biological activity. Dissolved Mn occurs at a somewhat higher level in the oxygen gradient than Fe. Consequently Mn ions are at too high redox potentials to permit the presence of detectable ferrous ions. As a result the manganous ion travels farther from the sediment than does the ferrous ion. Ferro-manganese complexes and formations are coprecipitated on the bottom of streams and lakes. Manganese oxides in bottom sediments occur in two forms: crusts or coatings and as nodules. Manganese is a vital trace element essential to bacteria, yeast, fungi, plants and animals. Manganese can have an indirect role on nutrient availability in fresh water. The detection of manganese is easily performed and sensitivity is extremely good.

922. Kleerekoper, H. 1973. Effects of copper on the locomotor orientation of fish. U.S. Environ. Protect. Agen. Rept. EPA-R3-73-045:1-97.

Effects of copper ions at subacute concentrations on locomotor orientation of goldfish (*Carassius auratus*), channel catfish (*Ictalurus punctatus*), largemouth bass (*Micropterus salmoides*), white sucker (*Catostomus commersoni commersoni*) and green sunfish (*Lepomis cyannelus*) were investigated in detail. In regions of water containing 11-17 μg/l Cu^{++} (as CuCl$_2$) in a shallow gradient, goldfish oriented toward the copper source ('attraction'). This response is reduced in a somewhat steeper gradient. In steep gradients significant but no absolute avoidance behavior occurred. Whether the response will be 'avoidance' or 'attraction' seems to depend on the slope of the gradient to which the fish is exposed. Even in steep gradients, the 'avoidance' behavior is reversed to 'attraction' when the copper ions interact with a temperature slightly higher (0.4°C) than that of the surrounding copper-free water. The interaction creates a new stimulus configuration which is different from those formed by the two variables separately. The orientation of the largemouth bass is not affected by copper ions at the concentrations tested. Channel catfish are weakly attracted by the copper-containing water and green sunfish significantly increase time spent there. Suckers significantly but not absolutely 'avoid' such water through changes in turning behavior.

923. Kleerekoper, H., G.F. Westlake, J.H. Matis, and D.J. Gensler. 1972. Orientation of goldfish (*Carassius auratus*) in response to a shallow gradient of a sublethal concentration of copper in an open field. Jour. Fish. Res. Bd. Canada 29(1):45-54.

In slowly flowing water, goldfish changed their locomotor behavior upon entering a mass of water containing shallow gradients of copper chloride. The concentration was 11 to 17 μg/l Cu^{++} in most of this mass, with small isolated pockets containing maximally 50 μg/l. The amount of time spent by the fish, the average size of turn, and the variance of the size of turn increased in the "polluted" region. The orientation of the fish in this region deviated consistently in the upstream direction resulting in the increase in time spent in the area of highest concentration. Comparison of the locomotor behavior of the fish in sodium chloride of the same concentration and the laboratory water established that the changes mentioned were in response to the copper rather than the chloride ion.

924. Kleinert, S.J., and P.E. Degurse. 1972. Mercury levels in Wisconsin fish and wildlife. Dept. Natur. Res., Madison, Wisc., Tech. Bull. 52:1-22.

Mercury determinations were made on 1,824 fish fillet samples representing 139 locations covering 52 of Wisconsin's 72 counties and boundary waters of Lake Michigan, Green Bay, Lake Superior, and the Mississippi River. All Wisconsin fish analyzed contained some mercury. Mercury levels in fish from waters removed from any known source of mercury use averaged 0.19 mg/l and ranged between 0.01 and 0.60 mg/l mercury. The highest mercury levels, averaging about 1 mg/l and ranging between 0.10 and 4.89 mg/l occurred in fish taken from sections of the Chippewa, Flambeau, and Wisconsin Rivers, all located below paper mills and below a mercury cell, chlorine-caustic soda plant. Different species vary in mercury content, and the larger fish often contain higher concentrations of mercury than do smaller fish of the same species taken from the same water.

Fish samples taken from the following areas contained mercury levels averaging above the 0.5 mg/l guideline established by the Food and Drug Administration for banning fish from interstate markets: the 350-mile stretch of the Wisconsin River below Rhinelander; 40 miles of the Flambeau River between Cedar Rapids and the junction with the Chippewa River; and 50 miles of the Chippewa River from the junction with the Flambeau River to Eau Claire.

Sportsmen were warned to limit consumption of fish from these waters to one meal per week, which would not constitute a health hazard.

Mercury determinations were made on 234 muscle and 220 wildlife liver samples. The common game species were sampled including deer, rabbits, squirrels, ruffed grouse, pheasants, puddle ducks, diving ducks and geese. Swans, pied-bill grebes, and blue herons, were also sampled. Mercury levels in muscle and liver tissue of most Wisconsin wildlife was well below 0.5 mg/l. Water birds, including waterfowl, contained more mercury than mammals or upland game birds. Livers of diving ducks, herons, and grebes approached or exceeded 0.5 mg/l. No geographic locations were noted where mercury seemed to be more concentrated in wildlife.

925. Klemmer, H., S.N. Luoma, and L.S. Lau. 1973. Mercury levels in marine biota. Government Repts. Announce. 73(10):76.

Benthic animals from Sturgeon Bank contained larger amounts of Hg and other metals than animals from similar environments on the coast of British Columbia. These high levels of metals are believed to be associated with the Vancouver City sewer outfall.

926. Kloth, T.C., and D.E. Wohlschlag. 1972. Size-related metabolic responses of the pinfish, Lagodon rhomboides, to salinity variations and sublethal petrochemical pollution. Contrib. Marine Science 16:125-137.

The effects of salinity variations on the respiratory metabolism of large and small L. rhomboides, in unpolluted water and water slightly polluted with a 0.5% petrochemical effluent, were investigated at near saturation DO levels and a near-optimum temperature of 10°C. A salinity range of 20-45^{o}/oo did not significantly affect the metabolism of large or small fish in unpolluted water. However, sustained swimming velocities were affected by salinity. The highest sustained swimming velocities were found at 20^{o}/oo, for both large and small fish; velocities decreased as salinity increased. Sustained swimming velocities of large pinfish decreased more than those of small pinfish. Sublethal pollution uniformly depressed small fish metabolism at all salinities. With large fish, pollution depressed metabolism at 20 and 32^{o}/oo, but elevated metabolism at 45^{o}/oo. Salinity had a statistically significant effect on respiration only with large fish in polluted water.

927. Knauer, G.A., and J.H. Martin. 1972. Mercury in a marine pelagic food chain. Limnology and Oceanography 17(6):868-876.

Phytoplankton, zooplankton, and anchovies collected in Monterey Bay, California, over a 10-month period were analyzed for total mercury. In general, mercury levels were low and no evidence of food chain amplification was observed. Temporal variations of Hg concentrations in phytoplankton were greater than those for zooplankton; however, no seasonal trends were observed for either group. Plankton samples were also collected on a transect between the Hawaiian Islands and Monterey. Mercury levels were approximately equal in inshore and offshore zooplankton. The highest average mercury concentration was found in phytoplankton-net samples from the open ocean that contained radiolarians and other small zooplankton forms as well as diatoms.

928. Kneip, T.J., G.P. Howells, and M.E. Wrenn. 1972. Trace elements, radionuclides and pesticide residues in the Hudson River. In Ruivo, M. (ed.), Marine Pollution and Sea Life, Fishing Trading News (books) Ltd., London: 169-173.

Studies of trace contaminants in the Hudson River and their bio-concentration in selected biota have been in progress since 1964. The relative distribution of radionuclides in the water, sediments and biota is similar to that reported in other areas for radionuclides and their associated stable elements. The natural radionuclides potassium-40 and radium-226 and -228 account for 80 to 90% of the activity in the river; the greater part of this is attributable to potassium-40. Except for tritium, man-made radioactivity in the river water is less than 1/100,000 of the AEC regulatory limits. Bioaccumulation of several man-made radionuclides have been studied. Of the nuclides selected (manganese-54, cobalt-60, iron-55, cerium-144, strontium-90) only manganese-54 and cobalt were found to be reconcentrated in measurable amounts. Accumulated activity does not increase with trophic level in the food web, but is governed by other factors.

Pesticide residues of the chlorinated hydrocarbon type have been shown to follow a pattern of increasing concentration with trophic level in many aquatic systems. This has been found to be true in the biota of the Hudson River with predatory fish and birds at the climax of the food web showing the highest concentrations, with some residues reaching concentrations of 1 to 3 μg/g sample. This implies a biological magnification of over 100,000 from the maximum concentrations observed of a few nanograms/liter in the water. While no data have been obtained which would indicate biological effects on the species or population observed, there is less than a factor of 10 between the observed levels, and those reported elsewhere to be lethal to some species. For at least two species of fish sampled, pesticide residues exceed the current Food and Drug Administration guideline concentrations for edible portions of fish.

929. Knight, L.A., Jr., and J. Herring. 1972. Total mercury in largemouth bass (Micropterus salmoides) in Ross Barnett Reservoir, Mississippi--1970 and 1971. Pesticides Monitor. Jour. 6(2): 103-106.

Total mercury in flesh of 73 bass collected between November 1970 and October 1971 was determined at intervals representing winter, spring, summer, and fall. Specimens ranged in weight from 0.10 to 3.15 kg. Mercury content ranged from less than 0.05 to 0.74 mg/kg total mercury; levels generally increased with weight of the fish.

930. Knoll, J., and P.O. Fromm. 1960. Accumulation and elimination of hexavalent chromium in rainbow trout. Physiological Zoology 33(1):1-8.

Rainbow trout exposed to 2.5 mg/l of Cr^{6+} in tap water accumulated chromium in concentrations exceeding the environment in the spleen, posterior gut, pyloric caeca, stomach, and kidney. With the exception of spleen, these organs are all capable of excretion; thus it is hypothesized that accumulation in these tissues may be correlated with excretion. The major route of hexavalent chromium into trout is probably the gills. Fish with esophageal occlusions had accumulations of chromium similar to those of normal fish in chromated water. Hexavalent chromium given via stomach tube was not accumulated to any degree by tissues other than those of the gastrointestinal tract in 24 hours. Hexavalent chromium probably crosses the gill membranes as a result of simple diffusion. Certainly a diffusion gradient existed between the environment and blood in these experiments to allow this diffusion to take place.

Either the chromium taken up by fish combines into a complex when it enters the blood, or nucleated fish erythrocytes behave differently than do mammalian red blood cells. A very low rate of increase in concentration was noted in blood. If erythrocytic binding were taking place, a high rate of increase in activity would have been observed.

Fresh-water elimination studies showed a rapid loss of chromium from the blood, liver, stomach, pyloric caeca, and posterior gut. A retention of chromium in the spleen and kidney was found to occur.

Trout exposed to concentrations of 2.5 mg/l of Cr^{6+} accumulated insignificant amounts of chromium in muscle tissue. Hence human consumption of the muscle portion of fish taken from waters contaminated with this or lower levels of chromium would probably represent no serious health hazard.

931. Knutson, D.W., and R.W. Buddemeier. 1973. Distributions of radionuclides in reef corals: opportunity for data retrieval and study of effects. In Radioactive Contamination of the Marine Environment, Int. Atom. Ener. Agen., Vienna, Austria: 735-746.

Autoradiography of sectioned massive corals from Eniwetok has revealed the presence of discrete bands of radioactivity identifiable with specific nuclear test series. X-radiographs of these and other corals show structural density variations which in comparison with the autoradiography demonstrates to be seasonal in nature. The coral structure thus contains a reasonably reliable internal calendar. Residual Sr-90 activities have been determined for the Eniwetok corals; and a Fanning Island coral has been used to reconstruct the uptake of excess C-14 at that location. In addition to permitting retrieval of past radionuclide concentrations as sampled by the corals, the method permits retrospective study of the organism's structural response to incorporation of the radioactivity. Results to date indicate that the macroscopic growth-rates and patterns of these corals are relatively unaffected by uptake of the observed amounts of radioactivity, and that reef corals can provide a valuable record of past variations in the marine concentrations and distributions of various radionuclides.

932. Koelling, J.J. 1971. Relationship of trace elements to algae growth. Wash. State Univ., Ph.D. Thesis: 1-131. Available from Univ. Microfilms, Inc., Ann Arbor, Mich., 48106.

Research directed toward finding correlations between algal populations and trace elements in a natural aquatic environment, Williams Lake (Washington), basically involved the identification and quantification of algal species as well as the measurement of 14 trace elements present in the lake water. Samples of water with algae were collected over a 13-month period to observe seasonal fluctuations in both algal species and trace elements. Collection was made from three different depths at one location where the lake was the deepest. Algae cell identification and quantitative estimates were determined by a microscopic count. Several physical and chemical measurements were also made including light transmission, alkalinity, acidity, pH, dissolved oxygen, temperature, phosphates, and nitrates. Results indicate that: (1) uranium, thorium, and cesium may be present in excess of growth requirements or may possibly have no affect on the growth rate of any of the algal forms studied; (2) mercury, although toxic in large quantities, may be utilized by diatoms in small quantities; (3) chromium, gold, cobalt, and antimony appear to be taken up by diatoms; (4) zinc and iron appear to be utilized by blue-green algae; (5) uptake of scandium, rubidium, and bromine by algae is not apparent, but may be possible.

933. Koeman, J.H., W.H.M. Peeters, C.H.M. Koudstaal-Hol, P.S. Tijoe, and J.J. M. de Goeij. 1973. Mercury-selenium correlations in marine mammals. Nature 245:385-386.

High levels of mercury may occur in the tissues of seals, dolphins and porpoises. In the Netherlands from 225 to 765 mg/kg (wet weight) in liver and from 9.9 to 31 mg/kg in brain have been detected in adult specimens of the common seal (Phoca vitulina) which were found dead. Brain concentrations were of the same order as those in the brain tissue of animals of various species poisoned experimentally by methylmercury compounds. As most of the mercury in marine fish is present as methylmercury, the high levels in seal brain suggest that these animals are affected by the toxic action of methylmercury compounds. Analyses of the methylmercury levels in the livers of six seals shot in the German part of the Wadden Sea and two adults found dead showed that only 2 to 14% of the total mercury was methylmercury.

The range for cadmium was 0.05 to 0.30 mg/kg, for arsenic 0.20 to 1.7 mg/kg and for zinc 25 to 34 mg/kg; on the other hand the concentration of antimony was found to be lower than the detection limit of 0.01 mg/kg. Further analyses were made of juvenile seals found dead, a number of adult seals shot, three porpoises (*Phocoena phocoena*) found dead along the Dutch coast, three bottle-nosed dolphins (*Tursiops truncatus*) which died in a dolphinarium, three dolphins (two *Delphinus delphis* and one *Lagenorhynchus obscurus*) collected near New Zealand and two dolphins (*Sotalia guianensis*) captured in Surinam. The concentration of mercury in the livers of marine mammals seems to be strongly correlated with the concentration of selenium, but not with any of the other elements determined.

Authors' results suggest that the correlation found reflects a causal relationship between mercury and selenium in marine mammals. As selenium has a protective effect against the toxic action of mercury compounds in experiments with rats and Japanese quail, it may have a similar effect in marine mammals. It has been suggested that mercury and selenium occur together in animal tissues and are associated to proteins by means of sulphur. The observation that most of the mercury in seal liver and brain was tightly bound and could not be recovered in the form of methylmercury may support this suggestion.

934. Koeman, J.H., and H. VanGenderen. 1972. Tissue levels in animals and effects caused by chlorinated hydrocarbon insecticides, biphenyls and mercury in the marine environment along the Netherlands coast. *In* Ruivo, M. (ed.), Marine Pollution and Sea Life, Fishing Trading News (books) Ltd., London: 428-435.

Since 1965 a toxicological surveillance has been made along the Netherlands coast. Molluscs, fish and sea birds were sampled and analyzed to follow the topographic distribution of the contamination, to note its effect on the food chain and to correlate tissue residues with effects which might be due to the intake of the contaminants. Among the sea birds a large colony of sandwich terns (*Sterna sandvicensis*) in the Wadden Sea was found suffering from serious mortality in 1965. The cause could be attributed to pollution with chlorinated hydrocarbon insecticides. In the same area the eiderduck (*Somateria mollissima*) seems to be endangered by the influence of pollution, particularly the female eider due to its peculiar breeding habits.

With neutron activation and gas chromatographic methods, total mercury and methylmercury levels were determined. High residues have been found in some eiderducks. It is not yet possible to evaluate the residue levels in terms of risk to the ecosystem.

935. Kopfler, F.C. 1974. The accumulation of organic and inorganic mercury compounds by the eastern oyster (Crassostrea virginica). Bull. Environ. Contam. Toxicol. 11(3):275-280.

Accumulation of mercury compounds by oysters was determined in two experiments, each utilizing three groups of 100 adult oysters. In the first experiment, conducted between 0 and 10°C, mercury levels were maintained at 50 μg/l with flow rate adjusted to one l/oyster/hr. In the second experiment, mercury levels were reduced to 1 μg/l, the water temperature varied between 25 and 35°C, and flow rates maintained at two l/oyster/hr because of the increased temperature. Controls were maintained for each study.

In the first experiment, the administration of organic mercury compounds was terminated after 19 days because many of the oysters in the groups receiving either methylmercury or phenylmercury were dead or moribund. Oysters classified as moribund exhibited slow, incomplete valve closure when disturbed. When oysters which survived 19 days of exposure to methylmercury and phenylmercury were placed in flowing seawater, about half in each group died within a week with all oysters in both groups dead within 14 days. Oysters exposed to inorganic mercuric chloride exhibited no apparent ill effects over a 42-day period of exposure to 50 μg/l of Hg.

Oysters concentrated mercury so rapidly that detection of differences in accumulation rates between experimentals was not possible; mean mercury levels in experimentals after one week was >1000X over controls. Mercury values in experimental oysters at 7 days, in mg Hg/kg wet weight, ranged between 15 and 25; for controls this was <0.02.

Copper and zinc levels were depressed in flesh from all three groups of oysters after one week exposure to mercury; in the two groups exposed to organomercury, Cu and Zn declined over the 19-day exposure. Copper and zinc levels in the oysters exposed to mercuric chloride began to increase during the third week and continued to do so until they were essentially the same as control values.

In the second experiment methyl- and phenylmercury were concentrated to essentially the same degree, while inorganic mercury was concentrated about 4 times less over a 74-day exposure. For organomercury compounds, values in mg Hg/kg wet weight were about 10 at 20 days and 30 at 60 days (a final concentration factor of about 30,000). For inorganic mercuric chloride, values were about 2 at 20 days and about 10 at 60 days.

Author concludes that continuous exposure of the eastern oyster to even one μg/l mercury in any of the three mercury compounds studied, caused oysters to rapidly concentrate mercury in their tissues far in excess of the 0.5 mg/kg wet weight "action guideline" established by the Food and Drug Administration.

936. Kosta, L., A.R. Byrne, P. Stegnar, and V. Zelenko. 1972. Uptake of mercury by plants and its distribution in living organisms in an environment with increased concentration of this element. *In* Radiotracer Studies of Chemical Residues in Food and Agriculture, Int. Atom. Ener. Agen., Vienna: 47-59.

Studies of the area around a mercury mine at Idrija were extended to include analysis for methyl Hg. The ratio of methyl Hg/total Hg in fish increased with increasing distance downstream from the mine, approaching 1 at a distance of 35 km. Hg and other elements were measured in vegetation, and Hg uptake by rabbits from vegetation. In rabbits, Hg was checked regularly in blood, urine, and feces. The analytical technique was based on reaction of methyl Hg cyanide vapor with either cysteine or glutathione extraction into benzene, and gas chromatography. The sensitivity was 1 µg/l using 0.1-1.0 g samples.

937. Krenkel, P.A. 1973. Mercury: environmental considerations, part I. Critical Reviews in Environmental Control 3(3):303-373.

The mercury problem is defined in relation to its sources, environmental distribution, biological transformations, decontamination potential and physiological effects. Included are additional sections on total mercury analysis and methylmercury analysis in which are reviewed sample preparation and methods of analysis.

938. Krishnamoorthy, R.V., and A. Venkatramiah. 1971. Kinetic changes in flexor myosin ATPase of *Scylla serrata* adapted to different salinities. Marine Biology 8:30-34.

Kinetic properties and the activation energy of flexor muscle myosin ATPase were investigated in the estuarine crab *Scylla serrata*. These properties varied at different salinities, but the extractability of the enzyme remained unaltered. The qualitative changes upon salinity adaptation are discussed with reference to estuarine conditions.

939. Krüger, F. 1971. Mathematical analysis of combined temperature and salinity effect on the metabolism of *Tilapia mossambica*. (Teleostei). Marine Biology 8:147-153.

Others have presented experimental results on the influence of temperature and salinity on rate of oxygen consumption in Tilapia mossambica, with evaluation on the basis of the allometric function. The present paper analyzes data of a new temperature function. Using this formula, the author shows that in 50 and 100% sea water, curves for logarithmic values for given body weights are parallel to each other; only the slope is different for the two salinities. In fresh water, the logarithmic temperature curves diverge. Results from the literature clearly demonstrate that it is not possible to explain differences in respiratory metabolism of Tilapia on the grounds of energy expenditure for osmoregulation. Author concludes that differences in rate of respiration are caused by differences in ionic composition of the internal milieu in different salinities.

940. Kucherova, F.N. 1972. Cation composition of the sperm cells and seminal fluid of Vimba vimba (L.). Jour. Ichthyol. 12(4): 666-670.

The following elements were detected in an ash residue of the sperm cells of the teleost Vimba vimba (L.) by microanalytical techniques based on crystal optics and the use of the spot test method: K, Na, Mg, Li, Cs, Sr, Al, Cr, Be, Ti, Nb, La, Mn, Zn, Fe, Co, Ni, In, Ag, V, Hg, Pb, Tl, Cu, Cd, Bi, Pd, Sb, Sn, Mo, Se, Te, Pt, Ir, and Re. The elements detected in an ash residue of the seminal fluid were K, Na, Mg, Li, Rb, Cs, Ca, Sr, Ba, Al, Cr, Be, Ti, Zr, Th, La, Ta, Mn, Zn, Fe, Co, Ni, Ag, Hg, Pb, Cu, Cd, Bi, Ru, Pd, As, Sb, Sn, Mo, Te, Pt, Ir, and Re. Consideration is given to the role of the cations of the seminal fluid in neutralization of the acid products of the ovulated ovum at the time of insemination and in the intensification of some of the metabolic reactions occurring before the spermatozoa are already at its surface.

941. Kumar, H.D., and G. Prakash. 1971. Toxicity of selenium to the blue-green algae, Anacystis nidulans and Anabaena variabilis. Annals of Botany 35:697-705.

Comparison was made of toxic effects of selenate, selenite, selenomethionine, and selenopurine on different growth phases of Anacystis nidulans and Anabaena variabilis. These compounds were less toxic in culture medium containing sulfate than in sulfur-free medium. Growth-inhibitory effects of selenate and selenite were studied on algae grown on agar medium and in liquid mineral medium. Selenomethionine and selenopurine were studied only in liquid culture. Growth was estimated by measuring optical density of culture tubes and percent survival scored by colony counting. Dose-response curves of both algae suggest comparatively greater killing by selenite than by selenate. *Anacystis nidulans* is three times more tolerant to selenite and selenate killing than *Anabaena variabilis*. Selenite is more toxic in agar plate cultures and less toxic in liquid cultures than selenate. Cells grown in the highest growth-permitting concentration of selenite in liquid medium form a variable number of red granules. No such granulation occurs in cells treated with other seleno-compounds, indicating that the mode of selenite action in blue-green algae differs from that of other selenium compounds.

942. Kutty, M.N., G. Murugapoopathy, and T.S. Krishnan. 1971. Influence of salinity and temperature on the oxygen consumption in young juveniles of the Indian prawn *Penaeus indicus*. Marine Biology 11:125-131.

Routine oxygen consumption of very young juveniles (0.1 g) of *Penaeus indicus* was significantly influenced by ambient temperature and weight of the animal, but not by ambient salinity, when tested at salinities (7, 21, and 35^{o}/oo) to which they had been long-term (over 10 days) acclimated. Standard oxygen consumption of young juvenile prawns (1 to 3 g), subjected to step-wise changes in ambient salinity, from sea water to low salinity waters (2 to 6^{o}/oo), and measured after short-term (24 h) salinity acclimation at each step, was lowest at salinities where prawns such as those tested occur naturally (10 to 15^{o}/oo). The metabolic rates do not appear to have a direct relation to the osmotic gradient, even when the influence of "interfering" activity is eliminated. It appears that factors other than osmotic gradient will have to be sought in order to explain the metabolic patterns of *P. indicus* in relation to salinity.

943. Langley, D.G. 1973. Mercury methylation in an aquatic environment. Jour. Water Poll. Contr. Fed. 45(1):44-51.

Fish were used to compare mercury methylation of sediment samples from a contaminated river under controlled laboratory conditions. The fish concentrated methylmercury in their bodies, as measured by gas-liquid chromatography. Different locations varied in methylating capacity by a factor of nearly 40. Methylation did not relate directly to mercury concentration in sediments. Deposition of various layers of fluorspar tailings on sediments showed that a 2- to 3-cm layer decreased methylation by about 80%. The rate of methylation from sediments was extremely slow, indicating that mercury-containing sediments would require many decades to purge themselves naturally to background levels.

944. Lappenbusch, W.L., D.G. Watson, and W.L. Templeton. 1971. In situ measurement of radiation dose in the Columbia River. Health Physics 21:247-251.

By the use of lithium floride thermoluminescent dosimeters, comparative environmental dose measurements were made in the Columbia River upstream from an atomic reactor effluent discharge site, near the point of discharge and at a location downstream from the effluent outfall. These dose estimates were related to water depth, periphyton biomass, and concentration of radionuclides in periphyton. Periphyton growth upstream from the reactors and near the discharge site was greatest near the surface and decreased down to 6 m. This decline was attributed mainly to reduced light penetration with increasing depth. The rise in biomass concentration at the river bottom (6 m) was perhaps due to greater deposition of sediments on the artificial substrates. In the area of incomplete effluent mixing near the outfall, greater turbidity, higher temperatures and the relatively high concentrations of chemical pollutants, such as chromium, may have contributed to the reduced periphyton growth. Chromium, present in the effluent through the addition of sodium dichromate to the reactor cooling water to inhibit corrosion, is toxic to fish, particularly in the hexavalent form. The average dose rate near the effluent discharge site was >20x that of the downstream location, but the mean concentration of radionuclides measured in the periphyton at the outfall was only about 4x greater.

945. Laroze, A. 1955. Effect of poisons on fish. Anais fac. farm. Porto 15:77-111.

The time required to kill S. cephalus of 7-8 cm total length, was a function of initial concentration, and was nearly constant for ferric lactate ($1.6\text{-}9.8 \times 10^{-3}N$), Al chloride ($0.03\text{-}2.8 \times 10^{-3}N$) and Cu sulfate ($0.15\text{-}6.2 \times 10^{-3}N$) while for Hg chloride up to $10^{-3}N$ there was a rapid increase. Temperature studies showed that for Ag nitrate, Ba chloride, Pb acetate, uranyl acetate, Cu sulfate, NaF, and LiCl the time required to kill was nearly constant up to 15° after which it increased rapidly. For Hg chloride and ferric lactate, a minimum velocity of mortality was found around 15°C.

946. Larsen, I.L. 1971. Determination of Zn65 specific activity in various tissues of the California sea mussel, M. californianus. M.S. Thesis, Oregon State Univ. Available from Nat. Tech. Inf. Ser., Springfield, Va., as RLO-1750-78:1-66.

As the distance from the mouth of the Columbia River increased from 0 to 300 km, Zn-65 specific activity of the soft tissue of mussel decreased from about 700 to 100 nanoCi/gram of stable Zn. Analysis of stable Zn was more efficient and accurate by atomic absorption spectroscopy as compared with neutron activation. The specific activity of the food and water of the mussels was calculated using a simple model; the result agreed with measurements made on zooplankton sampled from within the Columbia River plume.

947. Lask, D.J., C.E. McKone, R.G. Young, and C.A. Bache. 1971. Rapid uptake of mercuric ion by goldfish. Environ. Science Technol. 5(11):1138-1139.

Mercuric ion is rapidly absorbed from the water by goldfish. The extent of absorption is dependent on mercury concentration and time of exposure. Other factors known to influence the toxicity of heavy metals to fish may also affect this uptake, including water hardness, temperature, pH, volume, the associated heavy metal anion, and the presence of other heavy metal ions. Mercuric ion in water is rapidly absorbed into the mucus externally secreted by fish, and its presence appeared to stimulate this secretion. Therefore, it was of interest to determine the proportion of 'absorbed' mercury which may have been present in the accumulated mucus. Of the total mercury, it was found that 79.3% was in the mucus. Others have reported that bacterial methylation of mercury occurs when mercuric ion is incubated with dead fish but only if the mucus is present which may make these findings significant.

948. Lasker, R., R.H. Tenaza, and L.L. Chamberlain. 1972. The response of Salton Sea fish eggs and larvae to salinity stress. California Fish and Game 58(1):58-66.

In laboratory experiments, Salton Sea water at salinities of 40^{o}/oo and higher adversely affected developing embryos and larvae of croaker, _Bairdiella icistia_, and the sargo, _Anisotremus davidsoni_. Embryos developed abnormally, hatching success diminished, and mortality of larvae was greater than in normal Salton Sea water at 37.6^{o}/oo.

949. Laumond, F., M. Neuburger, B. Donnier, A. Fourcy, R. Bittel, and M. Aubert. 1973. Experimental investigations, at laboratory, on the transfer of mercury in marine trophic chains. _In_ 6th Int. Symp. Médicale Ocean., Portoroz, Yugoslavia, Sept. 26-30, 1973:47-53.

Transfer of mercury in a pelagic chain (plankton, fish) and in a neritic chain with molluscs (plankton, mussel) was studied. The first trophic level was contaminated with water and the second at one and the same time with water and food (1st trophic level), as in natural conditions. Mercury at subtoxic concentrations was introduced into water either as Hg^{2+} ions or associated with natural and artificial organic compounds present in oceanic environments and in effluents. Under these conditions, transfer factors of mercury from sea-water to fish and molluscs were ca. 50 and 3,000, respectively.

950. Lawrence, J.M. 1968. Dynamics of chemical and physical characteristics of water, bottom muds, and aquatic life in a large impoundment on a river. Zoology-Entomology Dept., Ser. Fish. 6, Agric. Exper. Sta., Auburn Univ., Alabama, OWRR Final Project B-005-ALA:1-216.

Chemical and physical characteristics of waters at various depths and locations in a multi-purpose, 45,000 acre reservoir Lake Eufula on the Chattahoochee River, its headwaters and tailwaters, were determined at regular intervals over a 3-year period. Determinations included pH, temperature, turbidity, light penetration, conductance, dissolved oxygen, alkalinity, Ca, Mg, Na, K, Cu, Zn, orthophosphate, ammonia nitrogen, carbon, Fe, and Mn. Dried, cored bottom-soil samples and hydrosol samples were extracted with ammonium acetate and the following elements determined: Ca, Mg, Na, K, Cu, Zn, Fe, Mn, Cd, Cr, Ni, Co, Mo, Pb, and P. Samples of several species of rooted aquatic plants and several species of fish were collected, preserved by freeze-drying, ashed, ash dissolved in acid, and quantities of same elements listed above determined. Chemical and physical characteristics of reservoir waters were in a constant state of change. Generally, the total carbon content of water decreased during this period while the ammonia nitrogen and orthophosphates contents remained fairly constant. Chemical composition of soils and aquatic life also remained fairly constant. Zn, Cu, Pb, Cd and Cr content in aquatic life in the reservoir was greater than in tributary ponds.

951. Leatherland, T.M., and J.D. Burton. 1974. The occurrence of some trace metals in coastal organisms with particular reference to The Solent region. Jour. Mar. Biol. Assn. U.K. 54:457-468.

Measurements were made, by neutron activation analysis, of arsenic, cadmium, antimony, mercury and zinc in organisms and bottom muds, mainly from Southampton Water and the Solent. The values are on a dry weight basis and refer to whole organism soft tissues unless otherwise stated. Concentrations of mercury in algae ranged from 0.07 to 0.22 mg/kg and those in animal tissues from 0.06 to 1.9 mg/kg. The distribution of the element in various tissues of clam, *Mercenaria mercenaria*, was rather uniform, except that concentration in gills was about 2.5 times that of whole animal. Variations among organisms from different parts of the Solent area and comparisons with other regions suggested some possible influences of local waste discharge, but there was no evidence of major effects. Anoxic muds contained higher concentrations of mercury than occurred in unreduced surface layers, suggesting mobility in interstitial waters of the uppermost zone and fixation under reducing conditions. The average levels of cadmium in algae and fish from substantially unpolluted waters were 0.3 and 0.03 mg/kg, respectively, while the range for marine gastropod and lamellibranch molluscs was from 0.3 to 21 mg/kg. Increased concentrations, by about two orders of magnitude, were found in *Fucus serratus* and *Littorina littoralis* from the Severn Estuary. Bottom muds from areas of low pollution contained, on average, 0.6 mg/kg. Concentrations of arsenic in molluscs were usually in the range from 3 to 24 mg/kg, while fish muscle contained on average 5 mg/kg. *Sepia officinalis* (cuttlefish, mollusca) contained 73 mg/kg in mantle tissue; in both *Sepia* and *Mercenaria* concentrations of As were higher in gills than mantle. Relatively high concentrations of As occurred in *Tealia* (72 mg/kg) and in most of the algae examined (11-54 mg/kg). Antimony occurred usually in the range from 0.01 to 0.1 mg/kg, with low values in fish muscle; concentrations averaging 0.2 mg/kg were found in two ascidian species. The average concentrations of arsenic and antimony in bottom muds from Southampton Water were 14 and 1.0 mg/kg respectively.

952. Leatherland, T.M., J.D. Burton, F. Culkin, M.J. McCartney, and R.J. Morris. 1973. Concentrations of some trace metals in pelagic organisms and of mercury in Northeast Atlantic Ocean water. Deep Sea Research 20:679-685.

Several trace metals (Zn, As, Cd, Sb, and Hg) have been determined, by neutron activation analysis, in pelagic organisms, mainly crustaceans and fishes, collected mostly off northwest Africa and in the Azores region. Concentrations of mercury (0.06 to 0.38 mg/kg dry weight) showed no clear trend with trophic level. Organomercury analysis on two species showed that the element was present largely in the methyl mercuric form. Concentrations of cadmium which reached 13 mg/kg dry weight in *Systellaspis deblis* and *Oplophorus* sp., and of arsenic, which averaged 25 mg/kg dry weight in the crustaceans, tended to decrease in the tissues of fishes. Values for antimony which were all below 0.1 mg/kg dry weight, showed some indication of a similar trend. Concentrations of mercury in sea water from an adjacent area ranged from 17 to 142 ng/l, the highest concentration occurring in deep water.

953. Leduc, G. 1972. Changes of blood chloride and osmolarity in two stocks of salmon parr (*Salmo salar*) during short-term exposure to seawater. Canad. Jour. Zool. 50(7):1019-1021.

Two stocks of hatchery-reared salmon were tested for changes in blood chloride and plasma osmotic concentrations following transfer from freshwater to diluted seawater for periods up to 256 h. One group of fish originated from an anadromous population (Atlantic salmon) while the others were from a freshwater stock (ouananiche). The results suggest that young salmon from both groups have very similar osmoregulation.

954. Lee, S.W., and L.B. Trott. 1973. Marine succession of fouling organisms in Hong Kong with a comparison of woody substrates and common, locally-available, antifouling paints. Marine Biology 20:101-108.

Successional stages of macrofaunal fouling organisms on test blocks were exposed in the subtropical waters of Hong Kong. A comparison of 5 types of wood commonly used to build boats, and 5 types of locally available antifouling paints were made. Rafts holding the test blocks were exposed at 1 m depth from 24 March, 1970, to 23 October, 1970. The initial macrofoulers on the control (Chinese fir) were Balanus and Bujula, and the final dominance was a Styela-Mytilus community. On painted surfaces, the Balanus-Elasmopus community was dominant. Temperature, salinity, dissolved oxygen, and turbidity were recorded weekly during the test. A preliminary chemical analysis of percentage pigment and cuprous oxide content in the antifouling paints is presented.

955. LeGall, P., and J. Ancellin. 1971. Concentration factors for Cs 137, Ce 144, and Ru 106 in several species of edible marine mollusks and crustaceans. Available from Nat. Tech. Inf. Ser., Springfield, Va., as CEA-N-1488:1-17.

Concentration factors for edible parts of mollusks and crustaceans ranged from 100 to 300 for Ce-144 and from 4 to 10 for Cs-137. Uptake of Ru-106 by edible parts was negligible. Concentration factors for uptake of Ru-106 ranged from 4 to 11 for gill, 2 to 10 for hepatopancreas, and 3 to 28 for shell.

956. Leteux, F., and F.P. Meyer. 1972. Mixtures of malachite green and formalin for controlling Ichthyophthirius and other protozoan parasites of fish. Progr. Fish-Cult. 34(1):21-26.

Fish infected with protozoan parasites were treated with mixtures of malachite green copper-containing compound, and formalin. Laboratory tests suggested that mixtures of 0.05 mg/kg malachite green plus 15 mg/kg, 25 mg/kg or 50 mg/kg formalin were safe and effective in treating external protozoans andichthyophthirii on channel catfish

(Ictalurus punctatus) and that levels up to 0.2 mg/kg malachite green plus 33 mg/kg formalin could be used on goldfish. In field trials, in tanks and ponds, a treatment of 0.01 mg/kg malachite green with 24 mg/kg formalin provided excellent control of Costia, Trichodina, Chilodonella, Scyphidia, and Trichophrya in all cases after one application. With two exceptions, Ichthyophthirius was controlled by three applications on alternate days. Cleidodiscus was not affected by the treatments. In nearly all cases, Ichthyophthirius-infected fish showed marked improvement within 12 hr after the first application. Other external protozoans were greatly reduced and usually eradicated by the first treatment. Eradication of Ichthyophthirius was usually achieved after the second application. Under field conditions three treatments were used as a precaution to ensure successful control. The malachite green and formalin mixture proved effective against Costia in a single application.

957. Levitan, H., and J.L. Barker. 1972. Membrane permeability: cation selectivity reversibly altered by salicylate. Science 178(4056):63-64.

Intracellular recording techniques were used to investigate the effect of salicylate on the relative cation permeability of a membrane in large molluscan (Navanax inermis) neurons. Salicylate caused a reversible, dose-dependent decrease in the permeability of Rb, Cs, Na and Li ions relative to that of K ions. Changes in cation selectivity result from adsorption of salicylate anions to the membrane with subsequent increase in the density and field strength of anionic sites in the membrane.

957A. Lewin, J. 1966. Silicon metabolism in diatoms. V. Germanium dioxide, a specific inhibitor of diatom growth. Phycologia 6(1):1-12.

In enriched sea-water cultures inoculated with a mixture of algae and other organisms, concentrations of GeO_2 above 1.5 mg/l specifically suppressed the growth of diatoms. In experiments with 14 pure cultures of diatoms (10 species), 1 mg GeO_2/l sufficed to reduce the growth rates significantly; 10 mg GeO_2/l was even more inhibitory to growth, and in a few cases killed the cells. Phaeodactylum tricornutum, the most weakly silicified diatom, was the least sensitive to GeO_2 inhibition. In experiments with four selected marine species, an appropriate increase in the SiO_2 concentration of the medium reversed the inhibitory action of GeO_2 on growth. A similar effect of SiO_2 was observed in growth experiments with the fresh-water diatom Navicula pelliculosa. (A non-silicified green flagellate responded quite differently, its growth being unaffected by relatively high concentrations of GeO_2.) At these low concentrations, GeO_2 presumably had no effect on respiratory metabolism, since, even in concentrations of GeO_2 as high as 400 mg/1, oxygen uptake of N. pelliculosa was unimpaired. All of these experimental results are consistent with the hypothesis that GeO_2 is a specific inhibitor of silicate utilization.

958. Lewin, J., and C. Chen. 1971. Available iron: A limiting factor for marine phytoplankton. Limnology and Oceanography 16 (4):670-675.

Experiments on availability of iron in culture media were conducted with seawater from Hood Canal, Washington. When all nutrients (except Fe-EDTA) were added and the culture medium autoclaved, iron present in seawater was unavailable for growth of most of the six phytoplankton species studied. EDTA was effective in making such iron available for algal growth in culture media made with freshly collected seawater but not when the water had been stored some days. Both in stored seawater and in autoclaved culture medium, part of the soluble iron was converted into a particulate form.

959. Lewin, J.C., 1954. Silicon metabolism in diatoms. I. Evidence for the role of reduced sulfur compounds in silicon utilization. Jour. Gen. Physiol. 37:589-599.

Cells of the fresh water diatom Navicula pelliculosa may be grown in a mineral medium containing a low concentration of silicon. When transferred to a fresh silicate solution and incubated under nongrowing conditions such deficient cells rapidly take up silicon from the medium. Utilization of silicon is an aerobic process. When deficient cells are washed with distilled water or saline, their ability to utilize silicon is impaired whereas respiration is unaffected. The ability of washed cells to take up silicon can be partially restored with sulfate or ascorbic acid, and is completely restored by Na_2S, $Na_2S_2O_3$, glutathione, l-cysteine, dl-methionine, or ascorbic acid plus sulfate. The sulfhydryl reagent, $CdCl_2$ inhibits silicon utilization of unwashed cells at concentrations which do not affect respiration. This inhibition similarly is reversed by glutathione or cysteine. However, sodium iodoacetate or sodium arsenite inhibits respiration and silicon utilization at the same concentrations. The silicon taken up by deficient cells is deposited at the cell surface as a thickening of the existing silica frustules. Sulfhydryl groups in the cell membrane may be involved in silicon uptake by diatoms.

960. Lewin, J.C. 1955. Silicon metabolism in diatoms. II. Sources of silicon for growth of Navicula pelliculosa. Plant Physiol. 30:129-134.

N. pelliculosa has an obligate requirement for silicon. Growth is proportional to soluble silicon at low concentrations, and is most dense in media containing about 35 mg Si/l. Since the addition of 1.0% agar supplies 1.5 mg soluble Si/l to the nutrient medium, such media can support some diatom growth in the absence of any other source of silicon. The ash of agar, employed at a concentration equivalent to 0.1% agar, supplies 24 mg soluble Si/l and thus supports good diatom growth. By treatment with HF this silicon can be removed from agar ash, which thereby loses its essential growth factor. When 0.1% agar is added in the presence of adequate amounts of silicon, there is some acceleration of growth, possibly attributable to its action as a dispersing agent.

Orthosilicates, which react with ammonium molybdate, serve as suitable sources of silicon for growth of N. pelliculosa. Colloidal silica (Ludox) neither reacts with ammonium molybdate nor supports diatom growth unless it has first been depolymerized with alkali.

961. Lewis, A.G., P.H. Whitfield, and A. Ramnarine. 1972. Some particulate and soluble agents affecting the relationship between metal toxicity and organism survival in the calanoid copepod Euchaeta japonica. Marine Biology 17:215-221.

Particulate and water soluble agents were tested to determine their ability to affect the relationship between copper toxicity and the survival of Euchaeta japonica (Copepoda, Calanoida). Clay minerals and diatoms were two types of particles capable of affecting this relationship. Ascorbic acid, sewage effluent, and water extracts of humic acid and two types of soils exhibited the same capability. The ability of the water-soluble agents was compared with that of a known chelating agent in an attempt to quantify the activity of the agents.

962. Lewis, A.G., P. Whitfield, and A. Ramnarine. 1973. The reduction of copper toxicity in a marine copepod by sediment extract. Limnology and Oceanography 18(2):324-326.

Seawater extracts of marine sediments from two areas were added to copper-enriched seawater in which the prefeeding stages (egg, 2 nauplioid stages) of Euchaeta japonica (Copepoda; Calanoida) were maintained. Survival with the sediment extracts were greater than without, indicating an ability of some part of the extracted material to reduce the toxicity of the copper. The effect of the extracts was compared with that of a synthetic chelating agent to provide an "equivalent" value.

963. Li, M.F., and G.S. Traxler. 1972. Tissue culture bioassay method for water pollution with special reference to mercuric chloride. Jour. Fish. Res. Bd. Canada 29(5):501-505.

The effect of $HgCl_2$ on multiplication and respiration of mouse L-cells cultivated in suspension was studied. The nutritional history, growth phase, initial density of the cells, as well as the concentration of serum supplement used in test medium had significant effects on sensitivity of the bioassay system. It was concluded that cells used should be in the stationary phase at an initial cell density of approximately 2×10^5 per ml, and the test medium should be free of calf serum. Under the experimental conditions mercuric chloride at a concentration of 10 µg/l or less inhibited the cellular multiplication significantly; the results indicated that this assay procedure could be adequate for monitoring water quality. The cellular respiration method, however, was less sensitive, but simple and rapid with results being made available within a few hours, and therefore useful for screening or preliminary testing of heavily polluted samples.

964. Lipschuetz, M., and A.L. Cooper. 1955. Comparative toxicities of potassium cyanide and potassium cuprocyanide to the western black-nosed dace (*Rhinichthys atratulus meleagris*). New York Fish. Game Jour. 2:194-204.

Toxicities of potassium cyanide, and of potassium cuprocyanide having cyanide-to-copper mol-ratios of 4.0, 3.75, and 3.0, were measured by a flow through procedure. The toxicity decreased as the ratio of copper to cyanide increased. The 24-hour median tolerance limits for KCN and for the 4.0, 3.75, and 3.0 mol-ratios were 0.22, 0.38, 0.47, and 0.71 mg/l CN, respectively; the 4-hour median tolerance limits were 0.26, 0.53, 0.69, and 1.10 mg/l, respectively. These values were for one species of minnow, the western black-nosed dace, and for given conditions of temperature, pH, and dissolved oxygen. In spite of the decrease in toxicity due to the presence of copper, cuprocyanide solutions are sufficiently potent to constitute a pollutional hazard when present in industrial wastes.

965. Livingston, H.D., and G. Thompson. 1971. Trace element concentrations in some modern corals. Limnology and Oceanography 16(5):786-795.

Thirty-four species of scleractinian corals, including hermatypic and ahermatypic varieties, were analyzed for trace elements. Acid leaching has been used to infer the distribution of elements between the coral skeleton (acid-soluble fraction) and detrital phases (acid-insoluble).

Sr, U, Ba, Cu, B, Li, and Zn are generally present in the coral skeleton. Sr and U concentration, relative to Ca and to Ca in seawater, show only little discrimination but small variations do exist between species from the same environment, indicating species specific controls. Larger differences are found between hermatypic and ahermatypic corals. The concentrations of Sr and U are independent of temperature and may be a function of the coral metabolism and rate of skeletogenesis. Ba is not discriminated against, but there is marked discrimination against B and Li. Zn is generally discriminated against but some ahermatypic species show high Zn concentrations. Si, Ti, and Cr are mostly present in the detrital phase associated with the corals; the nature of the detritus often reflects the local environment. Fe, Mn, Co, Ni, Pb, and Sc are distributed variously between the detrital and nondetrital phases. High concentrations are found in ferromanganese-stained pelagic corals and in nearshore corals containing much detritus. The concentrations of these elements in clean, fresh corals indicate that they are discriminated against with respect to Ca uptake from seawater.

966. Lockhart, W.L., J.F. Uthe, A.R. Kenney, and P.M. Mehrle. 1972. Methylmercury in northern pike (Esox lucius): Distribution, elimination, and some biochemical characteristics of contaminated fish. Jour. Fish. Res. Bd. Canada 29(11):1519-1523.

Northern pike heavily contaminated with methylmercury were captured from Clay Lake, Ontario, and released in Heming Lake, Manitoba, an area relatively free of mercury. Mercury levels in muscle biopsy samples at the time of transfer and at subsequent recaptures indicated that only 30% was eliminated in one year. Distribution among various body tissues was essentially unchanged, those organs most heavily contaminated being lens, kidney, and liver in decreasing order. Biochemical profiles of blood serum constituents showed several differences between samples from the two lakes, especially in levels of inorganic phosphate, total protein, alkaline phosphatase, and cortisol. Serum values for transplanted fish tended toward those in the clean lake and we have concluded that biochemical profiles were sensitive to the environmental change.

967. Löfroth, G. 1970. Methylmercury, a review of health hazards and side effects associated with the emission of mercury compounds into natural systems. Natural Science Res. Coun., Ecol. Res. Comm., Stockholm, Sweden, Bull. 4:1-56.

Health hazards and side effects associated with the discharge of mercury compounds into natural systems are reviewed. Accidental poisoning in man by consumption of methylmercury dressed seeds has occurred. Water and airborne pollution by any mercury compound presents problems of large magnitude as mercury can be methylated biologically in several ecosystems. The most important effects of methylmercury to be screened for are the selective destruction of certain brain cells and the C-mitotic action on dividing cells. The data presently available indicate that the human fetus might be visibly affected at a methylmercury intake by the mother-to-be several times less than the intake which would affect nonpregnant adults. Methylmercury seems to have a biological half-life on the order of 70-200 days in man. The official Swedish legal limit in fish is 1 mg Hg/kg tissue, with a recommendation to limit the consumption of fish to one meal a week.

968. Lough, R.G., and J.J. Gonor. 1971. Early embryonic stages of Adula californiensis (Pelecypoda: Mytilidae) and the effect of temperature and salinity on developmental rate. Marine Biology 8:118-125.

Developmental rate increases linearly with temperature. Lowered salinity retards developmental rate, and development is abnormal below 26.3^{o}/oo. Larvae do not congregate at salinity interfaces, but avoid low salinities in gradient experiments.

969. Lough, R.G., and J.J. Gonor. 1973. A response-surface approach to the combined effects of temperature and salinity on the larval development of Adula californiensis (Pelecypoda: Mytilidae). I. Survival and growth of three and fifteen-day old larvae. Marine Biology 22:241-250.

Three-day old cultured larvae were more sensitive to reduced salinity than 15-day old larvae. However, the 15-day larvae showed a narrower temperature tolerance than the 3-day larvae. A. californiensis larvae survived over a wider range of temperatures near optimum salinities than at salinities near their lower tolerance limit, and conversely. Temperature and salinity ranges for maximum survival (10° to 15°C, 31 to 33^{o}/oo) were narrower than the ranges which occur within the estuary where the adult populations exist. Larval size did not increase markedly during the 15-day rearing period, and was not greatly affected by temperature or salinity. No statistically significant temperature-salinity interaction was found for either survival or growth.

970. Lough, R.G., and J.J. Gonor. 1973. A response-surface approach to the combined effects of temperature and salinity on the larval development of Adula californiensis (Pelecypoda: Mytilidae). II. Long-term larval survival and growth in relation to respiration. Marine Biology 22:295-305.

Mussel larvae were reared for 3 days, from fertilization to veliger stage, at optimum conditions (15°C, 32.2°/oo S), then transferred to experimental temperatures and salinities for 22 more days to determine effects of these factors on survival and growth. For larvae surviving to 25 days, maximum survival was at temperatures below 10°C and at salinities above 25°/oo. There was a progressive shift in temperature and salinity tolerance with age of larvae. The older larvae became more tolerant to reduced salinity, but less tolerant to high temperatures. Growth of larvae over 25 days of culture was slight, and relatively independent of environmental temperatures and salinities. Oxygen consumption of 3-day old veliger larvae measured at various T-S combinations generally increased from 7° to 18°C, and then sharply decreased from 18° to 21°C. A plateau of oxygen consumption from 9° to 15°C at 32.9°/oo indicated that larvae are adapted to oceanic rather than estuarine conditions. A comparison of 25-day larval survival, mean length, and growth, with oxygen consumption of 3-day old veliger larvae indicated that high temperatures (15°C, and above) coupled with reduced salinities (26.1°/oo, and below) were unfavorable for prolonged larval life.

971. Loveless, J.E., and H.A. Painter. 1968. The influence of metal ion concentrations and pH value on the growth of a *Nitrosomonas* strain isolated from activated sludge. Jour. Gener. Microbiol. 52(Part I):1-14.

A strain of *Nitrosomonas europaea* was isolated from activated sludge effluent by a dilution method which readily demonstrated the presence of contaminating heterotrophs and yielded a high proportion of tubes containing pure cultures of ammonia-oxidizing bacteria. Copper, sodium, calcium and magnesium stimulated growth of pure cultures, and effects of deficiencies of these metals were demonstrated. EDTA improved growth in the basal medium, and abolished the toxic effect of added copper; it was, however, inhibitory at low calcium concentrations. The effect of pH value on the growth of *N. europaea* appeared to be dependent on the metal ion content of the medium although the optimum pH value was always between 7.5 and 8.

972. Lovett, R.J., W.H. Gutenmann, I.S. Pakkala, W.D. Youngs, D.J. Lisk, G.E. Burdick, and E.J. Harris. 1972. A survey of the total cadmium content of 406 fish from 49 New York State fresh waters. Jour. Fish. Res. Bd. Canada 29(9):1283-1290.

Fish from New York State fresh waters were surveyed for total cadmium. The majority of samples contained 20 µg/kg or below. The remainder showed concentrations up to 100 µg/kg with only a few above this concentration. Fishes from central New York waters rarely contained cadmium greater than 20 μg/kg. Fish from Adirondack waters contained cadmium above 20 μg/kg most consistently. These higher concentrations may be related to generally higher background cadmium levels in this Adirondack area where many metallic ore deposits are located with which cadmium is typically associated. Cadmium accumulation only occasionally appeared species-dependent. No relation was obvious between total residues of the metal and size or sex of fish or age of lake trout. The cadmium concentrations observed are comparable to those commonly present in many other foods.

973. Lowman, F.G. 1963. Radionuclides in plankton and tuna from the Central Pacific. In Schultz, V., and A.W. Klement, Jr. (eds.). Radioecology. Reinhold Publ. Corp., New York: 145-149.

Three factors appeared to control the selective uptake of radionuclides from sea water by the plankton, omnivorous fish, and carnivorous fish studied. These were isotope dilution by the corresponding stable element or chemically similar element in the sea water, the tendency of divalent cations to complex strongly with biological substrates, and the biological requirements for certain elements in metabolic processes.

During the first 48 hours following fallout, plankton in the contaminated area accumulated radionuclides in approximately the same ratio as they occurred in sea water. After one week radioisotopes of cobalt, iron, and zinc were actively taken up by plankton in comparison to other radionuclides which were associated with plankton at percentages similar to those in sea water. Omnivorous fish which feed on plankton, almost completely excluded fission products, and on a comparative basis, concentrated zinc-65 and iron-55, 59, but discriminated against cobalt-57, 58, 60. Carnivorous tunas, which feed primarily on omnivorous fishes, discriminated in favor of zinc and manganese and against iron and cobalt in comparison to the relative percentages of these radionuclides in their food supply.

974. Lowman, F.G. 1963. Iron and cobalt in ecology. In Schultz, V., and A.W. Klement, Jr. (eds.). Radioecology. Reinhold Publ. Corp., New York: 561-567.

The roles of iron and cobalt in ecology are dependent upon their physical and chemical characteristics in the environment and upon the biological demand for these elements. Iron and, to a lesser degree, cobalt are important elements in the physiology of plants and animals. The introduction of radioisotopes of iron and cobalt may be used to determine the roles of these elements in the metabolic patterns and mass transfers within a given ecosystem. Most investigations of this type have been done in marine environments near nuclear weapons test sites. Plankton, collected from an area of sea water which had been contaminated with radioactivity for a period of six weeks, exhibited average concentration factors for radioactive iron and cobalt of 90,000 and 100,000 respectively, and contained the stable counterparts of these elements in about the same ratio as they were present in the water.

The roles of iron and cobalt in two food chains have been investigated in the marine environment of the Central Pacific. These include:

Water → plankton → omnivorous fish → carnivorous fish
and
Water → plankton → omnivorous fish → birds

In the first food chain, discrimination against cobalt-57, 58, 60 was progressive throughout the trophic levels. Iron-55, 59 was actively concentrated in the omnivorous fish, and it accounted for a reduced percentage of the total radioactivity in the carnivorous fish due to the presence of large amounts of zinc-65.

In the second food chain the birds, which feed primarily upon omnivorous fish and secondarily upon squid, did not retain significant amounts of the radioisotopes of cobalt or iron but retained a major part of the ingested zinc-65.

975. Lowman, F.G., and R.Y. Ting. 1973. The state of cobalt in seawater and its uptake by marine organisms and sediments. In Radioactive Contamination of the Marine Environment, Int. Atom. Ener. Agen., Vienna, Austria: 369-384.

Two methods, the critical pathway and the specific activity approach, have been used to predict hazards to man and other animals from the introduction of radionuclides into the marine environment. Valid application of the specific activity method is dependent upon the similarity of the physical-chemical forms of the introduced radionuclides and the corresponding natural element in the marine environment. The present work is concerned with the development of methods for investigating the chemical-physical forms of naturally occurring cobalt in seawater, the application of the methods to seawater in tropical areas and the uptake of the different forms of the element by marine organisms. Carrier-free inorganic Co-58 and Co-60 and high specific activity cyanocobalamin Co-57 were used as tracers for ionic and complexed cobalt. Stable cobalt in seawater, tagged with ionic and complexed radionuclides, were preconcentrated by standard methods and analyzed for stable and radionuclide content. The chemical yields for each form of radionuclide and the amounts of different forms which were found in seawater are reported. Uptake of ionic and complexed cobalt by suspended and bottom sediments and by phytoplankton, zooplankton, brine shrimp, marine clams, pelagic crustacea and the spiny lobster were measured. The results show that significant errors may occur if concentration factors for marine organisms, based on comparisons of the stable element in seawater and in the living organisms, are calculated without consideration of the chemical-physical forms of the radionuclide and the natural element.

976. Lowthion, D. 1974. The combined effects of high salinity and temperature on the survival of young Limanda limanda. Marine Biology 25:169-175.

Young specimens of the most common inshore flatfish, the dab Limanda limanda, in the area of a proposed concentrated brine discharge, off the Yorkshire coast (England), were subjected to high salinities over temperatures corresponding to an annual temperature range. The effect of temperature slowly declines with increased immersion time, and salinity becomes increasingly the more dominant effect. A significant salinity-temperature interaction was observed, which reached its peak effect at 3 h immersion. A 3-dimensional response-surface model of the mortality contours for salinity, temperature, and immersion time, was produced which may be used to set upper limits to the design of the effluent disposal system. It is concluded that, provided salinity does not rise above 55°/oo, it is unlikely that significant changes in L. limanda populations will occur.

977. Lucas, H.F., Jr., D.N. Edgington, and P.J. Colby. 1970. Concentrations of trace elements in Great Lakes fishes. Jour. Fish. Res. Bd. Canada 27(4):677-684.

The concentration of 15 trace elements was determined by activation analysis of samples of whole fish and fish livers from three of the Great Lakes: Michigan, Superior, and Erie. The average concentrations of 7 elements in 19 whole fish from 3 species were as follows: uranium, 3 μg/kg; thorium, 6 μg/kg; cobalt, 28 μg/kg; cadmium, 94 μg/kg; arsenic, 16 μg/kg; chromium, 1000 μg/kg; and copper, 1,300 μg/kg. Trace element concentrations varied with species and lake. Uranium and thorium varied with species, but not for the same species from different lakes. The levels of copper, cobalt, zinc, and bromine varied little between species and lakes. The concentration of cadmium, arsenic, and chromium varied with species and lake.

978. Ludlam, S.D., K.S. Hutchison, and G.E. Henderson. 1973. The limnology of Stockbridge Bowl, Stockbridge, Massachusetts. Mass. Water Resources Res. Cen. Comp. Rept. OWRR A-044:1-63. Available from Nat. Tech. Inf. Ser., Springfield, Va., as PB-221.

Stockbridge Bowl is a eutrophic hard-water lake. Mean annual gross primary productivity was ca. 4.9 g C per m^2/day. *Microcoleus lyngbyaceus* dominated the phytoplankton through much of the year and formed a productive metalimnetic plate during summer stratification. Silica never became limiting to diatom growth, despite a spring diatom pulse. Silica, calcium and magnesium all showed inverse clinograde distributions during periods of stratification and values in the hypolimnion began to rise before anoxia. Fall in Ca-Mg hardness and delayed rise in Si values in the summer epilimnion were caused by precipitation of marl and uptake of Si in the littoral zone. Surficial sediments were laminated and the laminae were approximately annual. Analysis of diatom communities in the sediment revealed rapid increase in productivity over the past quarter century associated with development of the watershed.

979. Lunde, G. 1973. Analysis of trace elements, phosphorous and sulphur, in the lipid and the non-lipid phase of halibut (*Hippoglossus hippoglossus*) and tunny (*Thunnus thynnus*). Jour. Sci. Fd. Agric. 24:1029-1038.

The following elements have been found in the lipid and non-lipid phases of samples of halibut and tunny: arsenic, selenium, lead, copper, cadmium, mercury, zinc, iron, and sulphur. A surprisingly high content of sulphur was observed in the lipid phase suggesting a new group of lipids. The results indicate, furthermore, a rather constant selenium to sulphur ratio in defatted meal while the corresponding ratio in the lipid phase is more variable. No accumulation of cadmium compared with zinc seems to take place.

980. Lutz, P.L. 1972. Ionic and body compartment responses to increasing salinity in the perch *Perca fluviatilis*. Comp. Biochem. Physiol. 42A:711-717.

The effect of osmotic and ionic stress on perch plasma, tissue, and whole body electrolyte composition was studied. Perch survived indefinitely in media up to 1/3 sea water (S.W.) in strength, with only K, Mg, and Cl showing moderate significant rises in plasma, and in muscle only K and Ca being higher than normal values in fresh water. As muscle water, chloride and sodium spaces and total body water are also maintained, a considerable degree of adaptive ionic regulation is indicated. All attempts to acclimate perch to 1/2 S.W. failed due to a breakdown of the ionic controlling mechanisms with all ions increasing greatly. Sodium and chloride invaded the muscle cells in large amounts and both muscle and whole body lost significant amounts of water. Liver tissue maintained its normal degree of hydration and the liver cells appeared relatively resistant to entrance by Cl. Mean increases point to the whole body being almost three times as permeable to Cl as Na in 1/2 S.W.

981. Lutz, P.L. 1972. Ionic patterns in the teleost. Comp. Biochem. Physiol. 42A:719-733.

The inter-relationships of ions in and between the major body compartments of Perca fluviatilis were studied. Na and Mg were the most tightly regulated of all ions and showed a highly significant inverse relationship in both plasma and cell. In tissue, hydration water uptake was mainly by the cell with changes in the extracellular space playing a minor role. It is suggested that ionic levels in the body fluids are in a dynamic relationship with each other and function as precise controllers of specific and general metabolic processes.

982. MacInnes, J.R., and F.P. Thurberg. 1973. Effects of metals on the behavior and oxygen consumption of the mud snail. Marine Pollution Bull. 4(12):185-186.

Behavior and oxygen consumption rates of adult mud snails exposed to five metals individually (arsenic, cadmium, copper, silver and zinc) and to one combination of two metals (cadmium and copper), were examined. Oxygen uptake of distressed and retracted snails was lower than that of controls after exposure to all individual metals except cadmium, which resulted in an elevation of oxygen consumption. The combination of copper and cadmium resulted in a lower rate than either metal alone.

983. Mackenthun, K.M., and W.M. Ingram. 1966. Algal growth aqueous factors other than nitrogen and phosphorus. Publ. WP-24, Fed. Water Poll. Cont. Admin., USDI, Wash. D.C.:1-41.

This selected bibliography of 399 entries, compiled for engineers and scientists confronted with applied control investigations related to pollutants, focuses attention on such factors and their effects of algae. The report is organized into sections, as follows, with numbers of citations indicated: general references, 15; antibiotics, 31; autoinhibitors, 11; environmental factors, 25; extracellular products, 31; hormones and auxins, 13; inhibiting metabolites, 24;

predation and grazing, 24; general references on trace metals and compounds, 29; boron, 14; calcium, 2; chlorine, 5; cobalt, 7; copper, 5; gallium, 1; iron, 2; manganese, 5; molybdenum, 12; silicon, 7; sodium, 8; vanadium, 3; zinc, 17; mixed elements, 15; viruses and parasites, 11; vitamin assay methods, 22; vitamin occurrence, 22; organismic requirements for vitamins, 27; syntheses of vitamins, 11. Citations are dated from 1903 to 1966 of which 69 citations are from 1960-1966.

984. Mackereth, F.J., and W.J.P. Smyly. 1951. Toxicity of copper in solution to the stone-loach. Nature 168:1130.

In June, 1951, stone-loach (Nemacheilus barbatulus L.), a teleost which had been kept alive in an aquarium since March, 1951, died when it became necessary to replace the water supply, which came from a nearby reservoir with lake-water from Windermere. Chemical analysis showed that the original water contained 0.15 mg/l copper (Cu^{++}) whereas the lake-water had 0.28 mg/l copper, presumably derived from the inflow pipes. Stone-loach, when placed in water containing copper in solution from 0.00 in steps of 0.05 to 0.30 mg/l copper, lived in concentrations less than 0.20 mg/l copper, but all except one fish died within 24 hours at concentrations of 0.20 mg/l and above. It is concluded that the fish died of copper poisoning.

985. MacLeod, J.C., and E. Pessah. 1973. Temperature effects on mercury accumulation, toxicity, and metabolic rate in rainbow trout (Salmo gairdneri). Jour. Fish. Res. Bd. Canada 30(4): 485-492.

Mercury toxicity in rainbow trout fingerlings were related to water temperature and to chemical formulation of the mercury. At 10°C, the LC-50 (24 h) concentration for mercuric chloride was approximately 30 times that for phenylmercuric acetate (PMA). LC-50 (96 h) values for mercuric chloride at 5, 10, and 20°C were 0.40, 0.28, and 0.22 mg Hg/liter. The velocity of mortality (V = reciprocal of time to death in hours), was linearly related to temperature. For a mercuric chloride concentration of 0.5 mg Hg/liter, $V = .002 + .0023t$, where t = temperature in °C. Temperature also affected accumulation rate of mercury in the fish muscle. At 5, 10, and 20°C, a mercuric chloride concentration of 0.1 mg Hg/liter in the water produced biological magnification factors of 4, 10 and 22X, respectively. PMA produced higher magnification factors of 80 to 100 at 10°C. Active metabolic rate, though increased by higher temperatures, was depressed by mercuric chloride, and higher temperatures augmented the depressant effect.

986. Maetz, J. 1971. Fish gills: Mechanisms of salt transfer in fresh water and sea water. Phil. Trans. Roy. Soc. London 262(842):209-249.

The teleostean gill is a multi-purpose organ, specialized for respiratory gas exchanges, clearance of waste products of nitrogenous metabolism and maintenance of acid-base and mineral balances. Structural studies reveal a complex epithelium. The chloride-cells are almost certainly the site of ion exchange in relation to salt balance. Functional studies show that the gill is responsible for the net absorption of Na^+ and Cl^- occurring in fresh water and extrusion of these ions in seawater. In fresh water, a coupling between endogenous NH_4^+ or H^+ and HCO_3^- excretion and Na^+ and Cl^- absorption is observed. In sea water active Na^+ excretion is linked with K^+ absorption from the external medium. In parallel, active Cl^- excretion occurs. The gill is also the site of Na^+/Na^+ and Cl^-/Cl^- exchanges which involve 25 to 75% of the internal NaCl per hour. The relative importance of simple diffusion and exchange-diffusion in these exchanges is assessed. Biochemical studies reveal two enzymes playing important roles in the ionic pumps: carbonic anhydrase and Na-K activated ATPase. Studies involving transfer of euryhaline fishes from low to high salinity, show that the switch from freshwater to seawater types of gill function is far from instantaneous. Synthesis or destruction of function sites and renewal of specialized cells are involved. The role of external or internal NaCl concentration changes as stimuli for these 'inductive processes' and the endocrine control of these functional changes are briefly discussed.

987. Maetz, J. 1972. Branchial sodium exchange and ammonia excretion in the goldfish Carassius auratus. Effects of ammonia-loading and temperature changes. Jour. Exp. Biol. 56:601-620.

Sodium influx and efflux and ammonia excretion by the gill have been studied as a function of external sodium chloride concentration in Carassius auratus before and after loading the fish with ammonia. No correlation between net sodium uptake and ammonia excretion is observed, either when the net uptake changes with an external sodium change or when net uptake increases with ammonia-loading. Branchial handling of chloride ions cannot explain this absence of correlation. Comparison of the concentrations of free base ammonia and of ammonium ions (NH_4^+) in both blood (dorsal aorta) and external medium at the end of the closed-circuit experiments on control or ammonia-loaded fish demonstrates that the gill is permeable to the ionized form of ammonia. An abrupt temperature decrease (16 → 6°C) affects the sodium influx much more than the sodium efflux. Sodium balance becomes negative unless the fish is ammonia-loaded. The observed effects of temperature are reversible when the fish is returned to 16°C. Branchial ammonia excretion is highly temperature-sensitive in control fish when metabolic production limits ammonia excretion. After ammonia-loading, when most of the ammonia cleared by the gill is exogenous, the effect of temperature on branchial permeability to ammonia suggests a passive transfer of ammonium ions. The contributions of the kidney and the gill in sodium loss and ammonia excretion are compared in intact and ammonia-loaded fish.

988. Maetz, J., and D.H. Evans. 1972. Effects of temperature on branchial sodium-exchange and extrusion mechanisms in the seawater-adapted flounder Platichthys flesus L. Jour. Exp. Biol. 56:565-585.

The effects of short-term and long-term temperature changes on the branchial components of sodium balance have been studied in the seawater-adapted flounder Platichthys flesus. When fish adapted to 6°C are compared with fish adapted to 16°C a disturbance of sodium balance is observed; while the plasma level of sodium remains constant, an increased internal sodium space can be demonstrated isotopically. Increase of the muscle sodium content accounts for only a small part of the extra sodium content of the fish. The increased sodium load is the result of an impairment of the sodium-extrusion mechanism in the gills, and is demonstrated by the disappearance of the Na/K exchange activity of the gills. The passive sodium fluxes (by simple diffusion or exchange-diffusion) decrease only twofold. Abrupt temperature changes in the 6-21°C temperature range are followed by instantaneous and reversible changes of the total sodium efflux, of the sodium lead observed after transfer into fresh water of the Na/Na exchange. The Na/K exchange, which corresponds presumably to the active sodium extrusion mechanism, shows in contrast a much greater temperature dependence. Abrupt transfer to higher temperatures (23-26°C) produces irreversible damage to the transport system.

No compensatory acclimatization of the flux rates is observed during adaptation in the 6°C environment.

The biological, physiological, ecological as well as biophysical implications of these findings are discussed. Particular emphasis is given to the problem of gill haemo-dynamics.

989. Majori, L., and F. Petronio. 1973. Marine pollution by metals and their accumulation by biological indicators (accumulation factor). In 6th Int. Symp. Medicale Ocean., Portoroz, Yugoslavia, Sept. 26-30, 1973:55-90.

Laboratory studies using soluble Cd^{++}, Cu^{++}, Pb^{++}, and Hg^{++} confirm their accumulation by the mussel and specify the hygienic dangers for mussel and man, as well as characteristics of the mussel as an indicator of marine pollution. A simplified model of correlation between pollution and accumulation is presented.

990. Malanchuk, J.L., and G.K. Gruendling. 1973. Toxicity of lead nitrate to algae. Water, Air, and Soil Pollution 2(2):181-190.

Fixation of radioactive carbon technique was used to measure toxicity of $Pb(NO_3)_2$ to five species of freshwater algae. Portions of unialgal cultures inoculated into low salt medium were used to test all species at 10, 20, and 30 mg/l Pb. This medium approximated the salt concentrations of natural aquatic environments. Three different cell weights were used for each concentration of Pb and for the control to determine a relationship between cell weight and toxicity. The concentration of Pb causing a 50% reduction of C-14-labelled CO_2 fixation as compared to the control = ED-50 (median effective dose). ED-50 values for three of the genera tested (Anabaena, Chlamydomonas and Navicula) ranged from 15 to 18 mg/l Pb. A desmid, Cosmarium, had an ED-50 of 5 mg/l. This species had a higher surface to volume ratio than other species tested and could account for the increased sensitivity. The ED-50 for Ochromonas was not obtained. Throughout this experiment the fixation of C-14-labelled CO_2 increased with increasing Pb concentrations and is not readily explained.

991. Martin, J.H. 1970. The possible transport of trace metals via moulted copepod exoskeletons. Limnology and Oceanography 15(5):756-761.

Concentrations of Ca, Cd, Co, Cu, Fe, Mg, Mn, Ni, Pb, Sr, and Zn in 10 surface-zooplankton samples were compared with the values determined for 12 samples collected at 100 or more meters. Average values for Cu, Fe, Mn, Ni, Pb, Sr, and Zn were higher in the deep samples. It was postulated that more of these elements had become adsorbed to copepod exoskeletons at greater depths because food-dependent molting rates were lower; thus more time was available for elemental adsorption to take place. If this hypothesis is correct, molted copepod exoskeletons may be important in biogeochemical cycles. Copepods are the most abundant multicellular animals in the world, and there are 11 cast exoskeletons for every adult; these slow-sinking exuvia may well be capable of taking up elements by adsorption-exchange long after leaving the living animals. Thus, a large total surface-area is provided on which important chemical reactions may take place.

992. Martin, J.H., and G.A. Knauer. 1973. The elemental composition of plankton. Geochimica et Cosmochimica Acta 37:1639-1653.

Phytoplankton samples, collected in Monterey Bay, California, were analyzed for their Pb, Hg, Cd, Co, Ag, Cr, Ti, V, Mn, Ni, Cu, Fe, Zn, Al, Mo, Ba, Sr, K, Ca, Mg, Na and SiO_2 content. The results of these analyses were categorized on a chemical basis and the sample data were placed in three groups: Group I, Ti not detected; Group II, Ti detected; and Group III, Sr concentrators present. Levels of most elements were higher in Groups II and III for a variety of reasons that are discussed in the text. The siliceous frustules, remaining after organic-matter digestion, were also analyzed for the elements listed above. Significant amounts of Al, Ti, Fe, Mn, Cu, and Zn were found.

Zooplankton and microplankton samples, collected in Monterey Bay, California; off the coast of Oregon; and on a transect between Hawaii and Monterey, were also analyzed for the elements listed above (except Si). In general, element levels in the inshore and offshore zooplankton were similar; however, the microplankton samples, in which strontium was highly concentrated, were almost always higher in Pb, Hg, Cu, Fe and Zn.

993. Martin, J.L.M. 1972. Study of the uptake, concentration and metabolism of strontium 85 by the decapod crustacean *Carcinus maenas.* Marine Biology 12:154-158.

Strontium is absorbed and retained by *Carcinus maenas*. The variations of the specific activity rates due to the retention of Sr-85 have been studied for the whole animal as a function of its size and activity of contaminating water. The same study has been carried out as a function of stages of intermoult cycles for both whole animal and organs and tissues likely to affect uptake, storing, or further metabolism of strontium in hepatopancreas, hypoderm, blood, gills, muscle and exoskeleton.

994. Mathis, B.J., and T.F. Cummings. 1973. Selected metals in sediments, water, and biota in the Illinois River. Jour. Water Poll. Contr. Fed. 45(7):1573-1583.

This study was designed to assess the degree of metal contamination in a large midwestern river. The river is utilized both by industries for manufacturing and waste disposal purposes and by cities as a source of potable water and a means of wastewater disposal. Analyses were made for copper, nickel, lead, chromium, lithium, zinc, cobalt, and cadmium in bottom sediments, water, tubificid annelids, clams and fishes. Metal concentrations were higher in sediments than in water and organisms. Clams and worms that inhabit the mud or mud-water interface exhibited the highest metal concentrations of any of the organisms. Fishes that are primarily carnivorous in nature exhibited lower mean muscle concentrations of copper, nickel, lead, chromium, zinc, and cadmium than did omnivorous fishes.

995. Mathis, B.J., and N.R. Kevern. 1973. Distribution of mercury, cadmium, lead and thallium in a eutrophic lake. Inst. Water Res., Mich. State Univ., East Lansing: 1-25. Available from Nat. Tech. Inf. Ser., Springfield, Va., as PB-221 993.

Concentrations were studied of mercury, cadmium, lead, and thallium in various components of a eutrophic lake. Five species of fishes, two species of aquatic macrophytes, zooplankton, feces from migratory geese, water and sediments were analyzed for the four metals. The study revealed that the bottom sediments act as a "sink" for all four metals. With the exception of mercury, highest concentrations were found in bottom sediments. Mercury was detected in fishes and sediments. Largemouth bass, one of the top carnivores of the lake, exhibited a positive correlation between length and weight versus mercury concentrations in axial musculature. The feces of migratory waterfowl had high concentrations of cadmium and lead. In view of the large numbers of waterfowl using the lake each year, and the large quantity of feces deposited within the drainage basin, it is suggested that this avenue may be one of the major sources of contamination for these two metals and that fallout from airborne particulate matter is secondary. Residual concentrations of the four metals in soil of the drainage basin were not determined. The primary source of mercury and thallium for the lake is presumed to be from fallout of airborne particulate matter.

996. Matida, Y., H. Kumada, S. Kimura, Y. Saiga, T. Nose, M. Yokote, and H. Kawatsu. 1972. Toxicity of mercury compounds to aquatic organisms and accumulation of the compounds by the organisms. Bull. Freshwater Fish. Res. Lab. 21(2):197-227.

This study confirmed that fish feeding on mercury-contaminated organisms from Minamata Bay, Japan, suffer from mercury poisoning. Results of studies of chronic toxicity to fish of toxic shellfish containing some methylmercury compounds and of various mercury compounds are discussed. In addition, results of studies on biological magnification of mercury compounds through the food chain from phytoplankton to fish, and on biosynthesis of organic mercury from inorganic mercury are considered.

997. Matson, R.S., G.E. Mustoe, and S.B. Chang. 1972. Mercury inhibition on lipid biosynthesis in freshwater algae. Environ. Sci. Technol. 6(2):158-160.

Whole cells of specimens of unicellular algae, *Ankistrodesmus braunii* and *Euglena gracilis*, were exposed to various concentrations of inorganic mercuric and methyl mercuric chloride to determine if inhibition of lipid biosynthesis was one of the toxic effects of mercury compounds. At a mercuric chloride concentration of 3.5 mg/l, chlorophyll synthesis was 98% inhibited and galactolipid synthesis was 50% inhibited in *A. braunii*. However, significant inhibition of both synthesis processes was detected at mercuric chloride levels less than 1.0 mg/l. For methyl mercuric chloride, a 2.0 mg/l level inhibited 98% of chlorophyll synthesis and 85% of galactolipid synthesis. These mercury compounds were also shown to specifically inhibit the galactosyl transferase activity in *Euglena* chloroplasts. These results could logically be extended to other photosynthetic organisms, including phytoplankton and other species of unicellular algae.

998. Matthiessen, P., and A.E. Brafield. 1973. The effects of dissolved zinc on the gills of the stickleback *Gasterosteus aculeatus* (L.). Jour. Fish Biol. 5(5):607-613.

Concentrations of 0.5-1.0 mg Zn^{2+}/l distilled water killed sticklebacks after 1-3 days, producing detachment and sloughing of epithelial cells, and coalescing of adjacent secondary lamellar epithelia. Cytoplasmic abnormalities included extensive vacuolation followed by swelling of nuclei and mitochondria leading to cellular disintegration. Many acutely poisoned fish recovered in zinc-free hard water, regeneration of epithelia being accompanied by a temporary appearance of chloride cells on the secondary lamellae. Concentrations of 2.0-6.0 mg Zn^{2+}/l hard water were not toxic over periods of up to 700 h. Extensive cytoplasmic abnormalities appeared, however, including the formation of membrane bounded vesicles and dense accumulations of metabolites. The most pronounced effect was the appearance of active chloride cells on the secondary lamellae. The possible involvement of chloride cells in the excretion of ions other than chloride is briefly discussed.

999. McColl, R.H.S. 1972. Chemistry and trophic status of seven New Zealand lakes. New Zealand Jour. Marine Fresh. Res. 6(4): 399-447.

The chemistry of surface and bottom waters of seven Rotorua lakes was examined monthly between April 1970 and April 1971 in relation to lake biology. Twenty-four parameters were measured, including dissolved oxygen, major ions, silica, phosphorus, nitrogen, algal pigments, and some trace elements. All lakes were warm monomictic, second-class lakes. The waters were soft and variations between lakes in composition of major cations and anions appeared to be related to catchment differences. The major cations and Cl ion varied little with season. Sulfate varied seasonally in the hypolimnia of the most productive lakes. Silica was abundant in all lakes, except one where diatoms were poorly represented. Depletion of silica by diatom populations was only observed in the two most productive lakes. All lakes except one showed anomalous silica distribution with lower concentrations in the bottom waters at all times. Copper and zinc varied little between lakes and depths, but showed marked peaks during winter circulation. Data acquired from the analyses were used to classify the lakes by trophic level. Algal growth was most vigorous during winter circulation and in some lakes a related phosphate 'depletion phase' occurred. Nitrate concentrations were low by world standards, except in the most productive lakes during winter circulation. Nitrite occurred irregularly in the surface waters of some lakes and in trace amounts in the hypolimnia of all lakes in late summer.

1000. McEnery, M., and J.J. Lee. 1970. Tracer studies on calcium and strontium mineralization and mineral cycling in two species of Foraminifera, *Rosalina leei* and *Spiroloculina hyalina*. Limnology and Oceanography 15(2):173-182.

Mineral cycling in two species of calcareous foraminifera was traced with Ca-45 and Sr-90. Incorporation of these radionuclides as well as S-35 and P-32 was proportional to growth when they were introduced into the system in the range of 1×10^4-1×10^5 dpm/ml of medium (Sr-90 specific activity $\sim$ 109 μCi/g; Ca-45 specific activity $\sim$ 160 μCi/g; S-35 specific activity $\sim$ 95 μCi/g; P-32 specific activity $\sim$ 2.03 mCi/g). Although C-14 was a good indicator of growth during the first 3 weeks, its usefulness declined as the cultures aged. Some Ca-45 and Sr-90 was adsorbed to dead tests. Both foraminifera were decalcified by treatment with 0.01% Na_2-EDTA in seawater at pH 8.1. Recalcification and growth took place when individuals were returned to control media. Ten to 0.1 μM 2-acetylamino-1,3,4-thiadiazole-5-sulfonamide (Diamox) inhibited Ca but not Sr incorporation into the test. Calcium and strontium were tightly bound to foraminiferan shells and under conditions of alkaline pH and low hydrostatic pressure these did not exchange with environmental ions.

1001. McIntyre, J.D. 1973. Toxicity of methyl mercury for steelhead trout sperm. Bull. Environ. Contamin. Toxicol. 9(2):98-99.

Sperm obtained from five fish were combined; 0.1 ml aliquots were removed and inoculated into test tubes containing mercury concentrations ranging between 1 and 10 mg/l. The sperm was left in solution for 30 minutes at 11°C, then combined with 100 steelhead eggs from a single female. Percentage of fertilization was determined on the 17th day. Reduced fertilization of eggs indicated that concentrations of mercury greater than or equal to 1 mg/l reduced sperm viability. At concentrations greater than 1 mg/l the reductions increased sharply.

1002. McIntyre, J.D. 1973. Effects of metals on fertilization and development in fish. In Heavy Metals in the Environment; Proc. Seminar conducted by Oregon State Univ., Corvallis, 1972: Oregon State Univ. Water Resources Res. Inst. Rept. SEMN WR 016.73:163-168.

A literature review shows that successful fertilization of fish may be prevented by toxic metals through effects on behavior. In long term studies of the effects of metals on various life history stages of the brook trout, males in exposure levels of 3.4 mg/kg cadmium were seized by severe muscle spasms as females began to move gravel in redd (nest) preparation. These males were generally unsuccessful in fertilizing the eggs and eventually died. Direct effects of metals on gamete survival may prevent successful fertilization. Results of an acute test in which samples of steelhead trout sperm were held in various concentrations of methylmercuric chloride for 30 minutes before they were combined with eggs indicated that at concentrations greater than 1 mg/l, sperm viability was markedly reduced. The sexual development of fathead minnows in methylmercury is arrested at 0.25 μg/l. Zebrafish that were permitted to spawn in several concentrations of phenylmercuric acetate produced fewer eggs at concentrations of 1 μg/l or more as compared to lower concentrations.

1003. McKim, J.M., and D.A. Benoit. 1971. Effects of long-term exposures to copper on survival, growth, and reproduction of brook trout (Salvelinus fontinalis). Jour. Fish. Res. Bd. Canada 28:655-662.

During a 22-month period, all developmental stages of the brook trout were exposed to copper (Cu) concentrations ranging from 32.5 to 1.9 μg/l. The highest concentration decreased survival and growth in adult fish and reduced both number of viable eggs produced and hatchability. Survival, growth, and reproductive success of adults in copper concentrations from 17.4 to 3.4 μg/l did not differ from the control (1.9 μg/l). Concentrations of 32.5 and 17.4 μg/l had marked adverse effects on survival and growth of alevins and juvenile fish. Effects of copper on alevins-juveniles from unexposed parents apparently are no different than the effects on alevins-juveniles from parents exposed to copper. The maximum acceptable toxicant concentration (MATC) for brook trout exposed to copper in water with a hardness of 45 mg/l (as $CaCO_3$) and a pH of 7.5 fell between 17.4 and 9.5 μg/l copper. The mean 96-hr LC-50 for 14-month-old brook trout exposed to copper was 100 μg/l, and the application factor, MATC/96-hr LC-50, lies between 0.17 and 0.10.

1004. McKim, J.M., and D.A. Benoit. 1974. Duration of toxicity tests for establishing "no effect" concentrations for copper with brook trout (*Salvelinus fontinalis*). Jour. Fish. Res. Bd. Canada 31:449-452.

Exposure of brook trout to sublethal concentrations of copper from yearlings through spawning to 3-month juveniles was found sufficient to establish a "no effect" concentration. No adverse effects were found on survival, growth, or reproductive capacity of trout exposed in a second generation from egg through spawning to copper concentrations (about 9.4, 6.1 and 4.5 µg/l) which had caused no adverse effects on their parents when exposed to similar concentrations from yearlings to spawning. Nor were any adverse effects found on survival or growth of their offspring when exposed to the same concentrations from hatching to age 90 days. Tissue residue analyses indicated no accumulation in gill, liver, kidney, or muscle of either first- or second-generation trout exposed to the various copper concentrations, and residues in unfertilized eggs from exposed females were similar to those in females not exposed to added copper.

1005. McKim, J.M., G.M. Christensen, and E.P. Hunt. 1970. Changes in the blood of brook trout (*Salvelinus fontinalis*) after short-term and long-term exposure to copper. Jour. Fish. Res. Bd. Canada 27:1883-1889.

Seven blood characteristics—red blood cell count (RBC), hematocrit (Hc), hemoglobin (Hb), plasma chloride (Cl), plasma glutamic oxalacetic transaminase (PGOT, L-aspartate:2-oxoglutarate amino transferase), osmolarity (Os), and total protein (TP)—were measured in brook trout exposed to three concentrations (67.5-69.2, 38.2-39.0, and 22.8-24.0 µg/l) of Cu for 6 and 21 days. Concentrations of 67.5-69.2 and 38.2-39.0 µg/l caused statistically significant increases in RBC, Hc (6-day only), Hb, PGOT, and TP (6-day only), whereas Cl and Os decreased during both exposure periods. Five blood characteristics (RBC, Hb, Hc, Cl, and PGOT) were also measured in brook trout, which were exposed for 337 days to Cu concentrations of 32.5, 17.4, 9.5, 5.7, and 3.4 µg/l. After this long-term exposure, no changes were observed in the blood except for a measurable decrease in PGOT values at 32.5 and 17.4 µg/l. The disappearance of initial blood changes, after extended exposure, suggests the transient nature of these early responses. Application of this study to the evaluation of the physical condition of fish and the possible long-range forecasting of reproductive success and survival of a species is discussed.

1006. McKone, C.E., R.G. Young, C.A. Bache, and D.J. Lisk. 1971. Rapid uptake of mercuric ion by goldfish. Environ. Science Technol. 5(11):1138-1139.

Mercuric ion has been shown to be rapidly absorbed from water by goldfish. The extent of absorption is dependent on mercury concentration and time of exposure. As has been previously shown with other metals, mercury was found to concentrate initially in the external mucus secreted by the fish. The presence of mercury in water appeared to stimulate this secretion.

1007. McLusky, D.S. 1970. Salinity preference in *Corophium volutator*. Jour. Mar. Biol. Assn. U.K. 50:747-752.

A salinity preference range of 10-30^{o}/oo has been found in the euryhaline amphipod *Corophium volutator*, by means of simple choice experiments. This preferendum has been shown to be stable, despite acclimation to either low or high salinities. The results are discussed in relation to previous ecological and physiological studies of *C. volutator*.

1008. McLusky, D.S., and V.E.J. Heard. 1971. Some effects of salinity on the mysid *Praunus flexuosus*. Jour. Mar. Biol. Assn. U.K. 51:709-715.

The population dynamics of the mysid crustacean *Praunus flexuosus* have been studied at Ardmaddy Bay, Loch Etive. A salinity tolerance range of 2-33^{o}/oo has been demonstrated, over which the body tissues experience the range 11-28^{o}/oo. Comparison is made between the osmoregulatory capacity of *Praunus flexuosus* and the closely related *Neomysis integer*.

1009. McNabb, R.A., and G.E. Pickford. 1970. Thyroid function in male killifish, *Fundulus heteroclitus*, adapted to high and low temperatures and to fresh water and sea water. Comp. Biochem. Physiol. 33:783-792.

Adult males were acclimated for 5 weeks to fresh water or sea water at 20° and at 28°C. Estimates of thyroid activity were made from thyroid cell height, colloid staining properties, the rate of loss of thyroidal I-131 and serum concentrations of I-131. Results indicate that the levels of radioactivity follow the sequence: FW20≤FW28<SW20<SW28. Some of the possible interactions of salinity and temperature are discussed.

1010. Middaugh, D.P., and C.L. Rose. 1974. Retention of two mercuricals by striped mullet, *Mugil cephalus*. Water Research 8: 173-177.

The uptake and retention of phenyl mercuric nitrate (PMN) and mercuric chloride ($HgCl_2$) were studied in Mugil cephalus, the common saltwater mullet. Fish were exposed to calculated doses of 10, 50, 100 and 500 micrograms/l mercury of each toxicant in seawater for three hours. Thereafter, they were held in tanks with flowing seawater for 216 h. Fish were sacrificed at 72-h intervals during the holding period to determine levels of mercury in gill, liver and muscle tissues. Higher mercury levels were found in mullet exposed to PMN than in those exposed to equivalent concentrations of $HgCl_2$. No deaths occurred among mullet dosed with $HgCl_2$ whereas 58% of those exposed to the highest level of PMN died within 21 h of exposure. Mercury levels detected in tissues appeared to be related to the toxicant used, dose levels, and time of sampling after exposure.

1011. Miettinen, J.K. 1972. Some remarks on mercury as an aquatic pollutant and its implications. In Radiotracer Studies of Chemical Residues in Food and Agriculture. Int. Atom. Ener. Agen., Vienna: 61-68.

This review of 1970-71 literature includes occurrence of mercury in water, sediments, and marine fish; safe levels for fish in the diet; metabolism of methyl Hg; microbial methylation of Hg in sediments; and evaluation of the risk to populations. Dimethyl Hg (14% of the total Hg) volatilized when dredged sediment was exposed to air. Microbial methylation of Hg in sediments is possibly a detoxification mechanism of the organism, is slow, and requires oxygen. Freshwater fish contain 5-10 mg/kg in several areas of the USA, 1-5 mg/kg in 50 other areas. Swordfish exceed the 0.5 mg/kg limit.

1012. Miettinen, J.K., M. Heyraud, and S. Keckes. 1972. Mercury as a hydrospheric pollutant II. Biological half-time of methyl mercury in four Mediterranean species: a fish, a crab, and two molluscs. In Ruivo, M. (ed.). Marine Pollution and Sea Life. Fishing Trading News (books) Ltd., London: 295-298.

Analysis of the excretion rates of methyl mercury introduced by different ways into four marine organisms (Serranus scriba, a fish; Carcinus maenas, a crab; Tapes decussatus, a clam; and Mytilus galloprovincialis, a mussel) showed that a large fraction of the administered compound has a slow loss rate with a biological half-time from 267 (fish) till more than 1,000 days (mussel). These results were compared with those obtained from some other freshwater, brackish and marine crabs, molluscs, fish and a mammal. It was concluded that phylogenetically related species follow a similar pattern of methyl mercury excretion, with the biological half-time depending on temperature and on the way of methyl mercury's entry into the organisms, being longer after intramuscular injection than after peroral administration.

1013. Miettinen, J.K., M. Tillander, K. Rissanen, V. Miettinen, and Y. Ohmomo. 1969. Distribution and excretion rate of phenyl- and methylmercury nitrate in fish muscles, molluscs and crayfish. Proc. 9th Japan. Conf. Radioisotopes, Tokyo: 474-478.

Differences in toxicity, excretion rate, and distribution pattern of radioactive methylmercury were determined when administered orally, either as the ionic form $CH_3 Hg^+$, or bound to protein. Organ activity was determined after various time lapses by whole body counting of live animals. No significant differences were noted between fish in brackish water and in fresh water. Ten to 50% of the administered activity was excreted within one or two days. The remainder was excreted more slowly with phenylmercury nitrate having a shorter biological half-time than methylmercury nitrate. After about three weeks the highest concentrations of mercury were found in flesh, stomach, liver, ovary and kidneys. Results show that there is no essential difference in toxicity, distribution or excretion rate between ionic and protein-bound forms of methylmercury. From experiments with molluscs, mussels and crayfish it is evident that when mercury compounds are bound to the muscle protein (mercury compound injected) they have a slower excretion rate than when bound to the digestive organs (administered orally).

1014. Miettinen, V., E. Blankenstein, K. Rissanen, M. Tillander, J.K. Miettinen, and M. Valtonen. 1972. Preliminary study on the distribution and effects of two chemical forms of methyl mercury in pike and rainbow trout. *In* Ruivo, M. (ed.). Marine Pollution and Sea Life. Fishing Trading News (books) Ltd., London: 298-303.

This experiment was performed in order to establish: differences between "free" ionic form of methylmercury and protein-bound form of methylmercury in toxicity to pike; distribution of radioactivity after administration of these two methylmercury compounds labelled by Hg-203; and pathological and histopathological changes in organs of pike after oral administration of two methylmercury compounds. The "free" ionic form was applied as a water solution of $CH_3{}^{203}HgNO_3$ with carrier (0.5 μCi/mg Hg). The protein-bound form was made by adding fresh cow's liver homogenate to the water solution of $CH_3{}^{203}HgNO_3$ with carrier and incubating the mixture for 24 h at room temperature (22°C).

Administration was done orally in three to four small doses at intervals of 2 to 3 days. Five pike (mean weight 300 g) were given ionic MeHg to a final mean total dose of 12.1 mg Hg/kg (retained) and to five pike (mean weight 340 g) a final mean total dose of 24.7 mg Hg/kg protein bound MeHg, respectively. In addition, six control pike with no activity given were kept in the same aquarium. The mean life span for pike given ionic MeHg was 33 days; for those given protein-bound MeHg it was 18 days.

The approximate LC-50 (30 day) value for both of these compounds was 15± 3 mg Hg/kg fr. wt. The histopathological symptoms of these methylmercury compounds were similar. Kidneys and pseudobranchiae were the most damaged organs. No noticeable difference was observed in distribution pattern between these two methylmercury compounds.

When ionic methylmercury was orally administered as a single dose to seven rainbow trout (220 g) giving a mean body burden of 11.9 mg Hg/kg, all died within 1.5 to 2 h. When the same amount of ionic or protein-bound methylmercury was administered in two portions with an interval of 1 to 2 days, only three fish out of 12 died after 47 to 71 days. The others remained seemingly healthy for at least 94 days. The temperature in these experiments was 18°C.

1015. Miller, S.F., and C.R. Wilke. 1972. Utilization of algae for water purification and protein production. M.S. thesis: 1-100. Available from Nat. Tech. Inf. Ser., Springfield, Va.

The use of algae, specifically Pandorina morum, as ion exchange beads for removal of strontium from low level radioactive waste streams was investigated and an economic analysis of a plant for this treatment made. The algae process was more costly than conventional ion exchange processes due primarily to the expense of separating algae from dilute suspensions. Phototaxis, utilizing Pandorina's tendency to swim towards light, as a separation mechanism at a reduced cost was also investigated. Application of algae as ion exchange beads demonstrated that the kinetics of absorption is sufficiently fast so that equilibrium is obtained in < 2 min.; another experiment indicated that the mechanism for cation uptake is probably ion exchange. Plant design was compared for treating 4000 l of low level radioactive waste every 2 min.; the process employing algae as ion exchange beads costs 3x more than conventional ion exchange. Cheap means of separation would not only increase the feasibility of the algal process but would also lower the cost of producing algae as food. An analysis of Pandorina morum showed that 28-40% of the dry weight can be removed as amino acids. Further investigation of Pandorina as a food source is warranted.

1016. Minckley, W.L., J.E. Craddock, and L.W. Krumholz. 1963. Natural radioactivity in the food web of the banded sculpin Cottus carolinae (Gill). In Schultz, V., and A.W. Klement, Jr. (eds.). Radioecology. Reinhold Publ. Corp., New York: 229-236.

Consideration of life history and radioecology of the teleost Cottus carolinae, reveals that most radioactivity results from natural decay and some from fallout. Biota of the ecosystem accumulate measurable amounts, mostly uranium-238 and thorium-232 as determined by detection of bismuth-214 and actinium-228 on a gamma spectrometer, but also Sr-90 and Cs-137 to a lesser extent as determined radiochemically. In the food web of Cottus carolinae, radioactivity concentrates at the producer level, with decreased amounts at higher trophic levels involving animals. Animals, fed mostly on diatoms and blue-green algae, generally contained the most radioactivity.

Fishes and larger invertebrates including crabs and insects contained radioactivity with levels varying according to size of individual animal. Smaller animals contained more radioactive materials per unit weight than larger ones. Actual metabolic changes seem to be as important in determining amount of retention and accumulation of radiomaterials as are amounts of the radiomaterials ingested. Similarly, cumulative amounts of radioactivity taken in as food, compared with ever-increasing body burden, allow calculation of percentage of ingested radioactivity retained in the body. Percentages are relatively high during early life of sculpins, decreasing just before maturity, and increasing slowly throughout remainder of life. Lack of major variations in this level of retention indicate a certain metabolic need, or somewhat constant metabolic accumulation, which comprises approximately 2% of total radiomaterials ingested.

1017. Mitchum, D.L., and T.D. Moore. 1966. Study of water pollution problems which affect fish and other aquatic forms. Available from Game & Fish Lab., Univ. Wyoming, P.O. Box 3312, Laramie, Wyoming, Rept. FW-3-R-13:1-32.

The extent and effect of uranium mine effluent on fish and other aquatic organisms in the Medicine Bow River and contributing streams was studied. Samples of water, bottom mud, plankton, benthic organisms and aquatic plants were collected. Fish samples were collected only in July. The naturally occurring levels of uranium, in streams included in this study were determined to be about 5 μg/l. Uranium concentrations at the various stations affected by the mine effluent ranged between 2,000 and 60 μg/l. Data indicated that these relatively high uranium levels may be toxic to trout. The mine effluent did not appear to have any apparent adverse affect on plankton, periphyton, bottom fauna organisms, and fish species other than trout. Accumulated radiation could not be detected in bones of the fish specimens collected from the various stations. Findings show that uranium mine pollution exists in the Medicine Bow River drainage area and a potentially serious pollution problem exists downstream from the study area.

1018. Moore, W.S., and S. Krishnaswami. 1972. Coral growth rates using ^{228}Ra and ^{210}Pb. Earth and Planetary Science Letters 15(2):187-190.

Two radiometric methods were used to measure the growth rates of coral heads (Stephanocoenia sp. and Solenastrea hyades). The first method, based on decay of unsupported Ra-228 introduced into coastal waters mainly by diffusion from underlying sediments, follows the theoretical model and is applicable to growth measurements of the last 30 yr. The second method, based on decay of Pb-210 incorporated into the living skeleton, may be used to document major changes in growth during the past 100 yr.

1019. Moore, W.S., S. Krishnaswami, and S.G. Bhat. 1973. Radiometric determinations of coral growth rates. Bull. Marine Sci. 23: 157-176.

Radiometric methods based on Ra-228, Sr-90, and Pb-210 are used to measure the rate of coral growth. The Ra-228 and Sr-90 methods give consistent results. The Pb-210 method is not ideal, but may be used in some cases to document major changes in growth rates. By quantifying the time parameter in modern coral samples, chemical changes in the reef environment may be studied for the past 30 years.

1020. Morgan, W.S.G., and P.C. Kühn. 1974. A method to monitor the effects of toxicants upon breathing rate of largemouth bass, Micropterus salmoides Lacépède. Water Research 8:67-77.

An apparatus was designed to measure continuously the effects of nominal concentrations of copper, cadmium, phenol, ammonia and cyanide upon breathing rates in largemouth bass. Acute and sublethal toxic effects were indicated in a majority of cases by increased breathing rate. The use of this reaction and the monitoring apparatus to monitor a wide range of industrial pollutants was shown to be practicable. Consideration is also given to its possible application in local situations.

1021. Morgon, R.P. II, R.F. Fleming, V.J. Rasin, Jr., and D. Heinle. 1973. Sublethal effects of Baltimore Harbor water on the white perch, Morone americana, and the hogchoker, Trinectes maculatus. Chesapeake Science 14(1):17-27.

Possible sublethal effects of Baltimore Harbor water, which receives various industrial and domestic wastes, were investigated in bioassays with white perch and hogchokers. The tests were conducted in

170-liter polyethylene tanks containing full-strength Harbor water, half-strength Harbor water and water from the Patuxent River. Exposures were for 14 to 30 days for white perch and 7 to 28 days for hogchokers. After exposure, blood samples were collected for differential staining and bodies were dissected for enzyme, histology, heavy metal, and pesticide analyses. There were no significant variations in Cd, Cr, Cu, Fe, Hg, and Zn in the three tests. Dieldrin was the only pesticide found and variations were slight among the tests. However, physiological effects of Baltimore Harbor water included changes in thrombocyte, neutrophil, and basophil levels in white perch. Biochemical effects included increased LDH activity in the serum of white perch and hogchokers when exposed to Baltimore Harbor water, decreased acetylcholinesterase activity in white perch and hogchoker brains, and decreased catalase levels of the liver of both white perch and hogchokers. Sublethal effects were noted at the longer (28 and 30 day) exposures to the Baltimore Harbor water.

1022. Morisawa, M., and H. Mohri. 1972. Heavy metals and spermatozoan motility. 1. Distribution of iron, zinc, and copper in sea urchin spermatozoa. Contrib. Tamano Marine Lab., No. 187:1-6.

Sea urchin (*Pseudocentrotus depressus*, *Hemicentrotus pulcherrimus* and *Anthocidaris crassispina*) spermatozoa were fractionated into heads, midpieces, and tails as completely as possible, and the contents of Fe, Zn, and Cu in these parts determined by spectrophotometry and atomic absorption spectrophotometry. The concentration of Fe was the highest in the midpiece fraction, while Zn was concentrated in the tails as well as in the midpieces. Copper was found only in the midpiece fraction. Microtubules isolated from the tails also contained considerable amounts of Fe and Zn.

1023. Morrill, J.B. 1963. Morphological effects of cobaltous chloride on the development of *Limnaea stagnalis* and *Limnaea palustris*. Biol. Bull. 125(3):508-522.

The effect of cobaltous chloride ($CoCl_2$) on various developmental stages of the freshwater snails *Limnaea stagnalis* and *L. palustris* was studied. Eggs and embryos were treated for 24 hours with various concentrations of $CoCl_2$. Effective concentrations of $CoCl_2$ ranged from 1×10^{-5} to 1×10^{-4} *M* for *L. stagnalis* (about 1.3 to 13 µg/l of $CoCl_2$) and from 2×10^{-6} to 8×10^{-5} *M* for *L. palustris* (about 0.26 to 10.4 µg/l of $CoCl_2$). Variations in resistance to $CoCl_2$ were observed between species at the same stage of development, between eggs treated at different stages of development and between eggs from the same egg masses treated at the same stage of development. Treatment with $CoCl_2$ resulted in (a) separation of blastomeres, (b) vesicular and dumbbell-shaped exogastrulae, (c) arrested gastrulae, (d) veligers with a reduced larval liver, shell and foot, and with a fluid-filled body cavity containing few mesenchyme cells, (e) shell-less snails with a reduced larval liver and shell, and, (f) helmet-shelled snails with abnormally wide shell apertures.

Manganese, cadmium and nickel produced malformations similar to those caused by cobalt. The sequence of effective concentrations was Mn < Co < Cd < Ni.

Sections of normal and cobalt-treated embryos showed an inhibition of the differentiation and proliferation of mesenchyme cells of the body and foot and an inhibition of proliferation and enlargement of the endoderm cells of the larval liver.

Exogastrulae and hydropic exogastrulae and veliger larvae appear to be caused by an impairment in the development of the mesomeres plus a concomitant uptake of water by the blastocoel or body cavity. Arrested veliger larvae and the differences in their development are explained on the basis of variation in the functional capacity of their larval livers. The morphological evidence indicates that several characteristic malformations result from an inhibition of the cobalt-sensitive fourth quartette of micromeres and their derivatives, the mesomeres and larval liver cells. Author concludes that metal ion-reactive groups in the vegetal region of the Limnaea egg may be progressively segregated into the fourth quartette of micromeres.

1024. Morris, O.P., and G. Russell. 1973. Effect of chelation on toxicity of copper. Marine Pollution Bull. 4(10):159-160.

The effect of chelation on copper toxicity to the alga Ectocarpus siliculosus in culture is very marked. In the marine environment, much of the copper present will be rendered non-toxic by complex formation with organic material. Chelation will, therefore, tend to decrease the selection pressure and represents a major factor limiting evolution and establishment of copper tolerance in marine algae. This is particularly true of muddy environments such as are found in most docks and estuaries, and is important in the selection of algal genotypes in polluted marine ecosystems.

1025. Moshe, M., N. Betzer, and Y. Knott. 1972. Effect of industrial wastes on oxidation pond performance. Water Research 6(10): 1165-1171.

Cadmium, copper, nickel, zinc, and hexavalent chromium ions were tested in a bench-bioassay experiment for toxicity limits and possible application to experimental oxidation ponds. Domestic sewage was placed into test tubes where predetermined concentrations of metal ions were added together with known initial concentrations of the alga Chlorella sorokiniana. The test tubes were incubated under controlled illumination (1500 lx) at 29°C. Experimental containers of 50-70 l were fed with diluted domestic sewage (BOD equal 200 mg/l). Predetermined quantities of metal salts had been previously added to give the desired concentration of metal ions in the inflowing sewage. At the final stage of the study, an aquarium of 80 l capacity was operated as an experimental pond. To this pond a mixture of metal ions (Cr, Cd, Cu, Ni, and Zn) was introduced beginning with 3 mg/l and increasing to 12 mg/l of each ion. Samples taken from the ponds were subjected to the following test: pH, dissolved oxygen, BOD, MPN, algal count and determination of metal ion concentration. The samples were taken from the influent, effluent and bottom sludge. It was found that the metal ions are toxic, inhibiting Chlorella growth. However, when added at concentrations of 0.5-1.5 mg/l to influent of oxidation ponds, the ponds continued to operate normally. Higher concentrations of 3 and 6 mg/l did not adversely affect pond performance—not even a concentration of 6 mg/l of each ion (a total metal ion concentration of 30 mg/l). A mixture of 60 mg/l metal ions brought about a decrease in algal numbers and caused a sharp drop in dissolved oxygen concentration. It is believed that since high pH causes metal ions to precipitate, oxidation ponds operating normally above pH 8.0 will tolerate metal ions in sewage containing industrial wastes for a long time before sludge accumulation will affect pond performance.

1026. Motais, R., and J. Isaia. 1972. Temperature-dependence of permeability to water and to sodium of the gill epithelium of the eel Anguilla anguilla. Jour. Exp. Biol. 56(3):587-600.

The temperature dependence of diffusional permeability to water was studied in freshwater-adapted and seawater-adapted eels. The ratio of water permeability to sodium permeability is approximately 3 at 25°C, but falls to 1 at 5°C. This drop is mainly due to a diminution of water permeability, the temperature coefficients being much higher for water than for sodium. The relatively independent variations of water and sodium permeabilities in seawater-adapted fish probably indicate a certain dissociation between water movements and salt movements. In the freshwater-adapted eel the osmotic permeability is considerably higher than diffusional permeability, which supports the previously advanced hypothesis concerning the presence of water-filled channels in the branchial epithelium. In the seawater-adapted eel the osmotic permeability is lower than the diffusional permeability, this difference being greater the lower the temperature. This surprising result must signify either that the osmotic pressure difference between blood and sea water does not represent the true osmotic gradient across the membrane, or that a reabsorption of water linked with a movement of solutes occurs in a specialized region of the gill.

1027. Motais, R., and J. Isaia. 1972. Evidence for an effect of ouabain on the branchial sodium-excreting pump of marine teleosts: interaction between the inhibitor and external Na and K. Jour. Exp. Biol. 57(2):367-373.

In all marine fish, both stenohaline and euryhaline, the net sodium excretion by the gill, compensating for intestinal absorption, is the result of a Na_{int} - K_{ext} exchange. In a euryhaline fish, such as the eel, in which a sodium exchange diffusion (linkage of sodium influx and outflux) also occurs, the two kinds of exchange (Na-Na and Na-K) can be regarded as alternative modes of behavior of the same transport system. In normal seawater both exchanges take place at the same time; in K-free seawater the system exchanges Na for Na exclusively and in Na-free solution containing K the system exchanges Na for K exclusively. The transport system is located on the external membrane since it is inhibited by ouabain added in the external medium. The Na-K process is ouabain-sensitive but K can antagonize the inhibitory action of the glycoside. The Na-Na process on the other hand is not ouabain-sensitive.

1028. Mount, D.I. 1966. The effect of total hardness and pH on acute toxicity of zinc to fish. Air and Water Pollut. Int. Jour. 10:49-56.

Four-day tests of the toxicity of zinc sulfate to minnows were made at 3 pH levels (6, 7 and 8) and 3 total hardness levels (50, 100 and 200 mg/l as $CaCO_3$). Continuous-flow tests were used, and zinc concentrations were measured for each test. Zinc was most toxic at pH of 8 and hardness of 50 mg/l and least toxic at pH 6 and hardness of 200 mg/l. At any given hardness, zinc was always more toxic at a high pH than at a low pH. The results are in disagreement with most published work possibly because the flow-through test system, unlike static test systems, keeps precipitated zinc in suspension.

1029. Nakamura, R., Y. Suzuki, E. Kawachi, and T. Ueda. 1972. The loss of radionuclides in marine organisms during thermal decomposition. Jour. Radiation Res. 13(3):149-155.

Losses of Cs-137, Ru-106-Rh-106, Zn-65, Co-60, Fe-59, Zr-95-Nb-95, and Ce-144 from bivalve and green algae tissues during dry ashing at temperatures of 450, 550, and 800°C and with ignition times of 12, 24, and 48 hr were studied. Bivalve ignition was not complete in 24 hr, and algal ignition was not complete in 12 hr. The most desirable bivalve ashing conditions were 450°C and 48 hr for Cs-137 and 550°C and 12 hr for other radionuclides; optimum conditions for green algae were 450°C and 24 hr for Cs-137, Ru-106-Rh-106, and Zn-65 and 550°C and 12 hr for other radionuclides.

1030. Nakatani, R.E., and R.F. Foster. 1963. Effect of chronic feeding of Sr^{90}-Y^{90} on rainbow trout. In Schultz, V., and A.W. Klement, Jr. (eds.). Radioecology. Reinhold Publ. Corp., New York: 359-362.

The approximate quantity of orally administered Sr-90-Y-90 required to produce radiation damage and the syndrome involved in yearling rainbow trout was determined. Growth depressions and significant mortalities were observed when trout were fed 0.5 microcuries Sr-90-Y-90 per gram of fish daily for 21 weeks, but two other groups of lower treatment levels of 0.05 microcuries and 0.005 microcuries Sr-90-Y-90 per gram of fish did not differ from the control. A pronounced leukopenia was observed for the high level treatment group at the end of the test. The growth in weight of all groups with the exception of the high group was described as exponential growth during the 21 weeks.

About 25% of the administered dose was retained in all treatment groups. The total body burden of a 309 gram trout in the high group was in the order of 2,200 microcuries. At the end of the test no obvious damage was observed in low and medium groups; however, six months post-treatment leukopenia was indicated in the medium group. Clinically observed effects for the high group were anorexia, weight loss, listlessness, and a diminished response to external stimuli.

1031. Narbonne, J.F., J.C. Murat, and A. Serfaty. 1973. Intoxication par le nitrate de plomb chez la Carpe (Cyprinus carpio L.): données sur les modifications des métabolismes nucléoprotéique et glucidique. Comptes rendus des séances de la Société de Biologie 167(3-4):572-575.

Carp exposed for six weeks to 3.5 mg/l of Pb^{2+} (as lead nitrate) in the water at 20°C survived apparently unaffected. However, lead-exposed fish exhibited significantly higher glycogen levels in plasma, liver, and heart.

1032. Neely, W.C., R.C. Smith, R.M. Cody, J.R. McDuffie, and J.A. Lansden. 1973. Biological and photobiological action of pollutants on aquatic microorganisms. Alabama Water Resources Res. Inst., Auburn Bull. 9, OWRR A-017-A1A(2):1-122. Available from Nat. Tech. Inf. Ser., Springfield, Va., as Pb-220 167.

Various aspects of biological and photobiological action of pollutants on aquatic microorganisms have been explored in a series of studies covering a wide range of chemical species and two classes of aquatic microorganisms, paramecia and bacteria. Certain metal ions, insecticides, polycyclic amines and mycotoxins are capable of drastic alteration of the life processes in test strains of either bacteria or paramecia or both. In some cases concurrent exposure to light and the pollutant was necessary and in others the toxic and/or mutagenic reactions were independent of light exposure. In particular the uranyl ion, beta naphthyl amine, and aflatoxin B1 were phototoxic while the insecticide, phygon, was strongly darktoxic. All agents affected Paramecium caudatum and all but aflatoxin B1 affected Escherichia coli. In addition, the uranyl ion caused morphological mutations in E. coli. The public health hazard connected with such alterations in life-cycles resulting from water-borne pollutants is difficult to assess from laboratory data.

1033. Nelson, D.J. 1963. The strontium and calcium relationships in Clinch and Tennessee River mollusks. In Schultz, V. and A.W. Klement, Jr. (eds.). Radioecology. Reinhold Publ. Corp., New York: 203-211.

Shells of a number of species of clams from the Clinch and Tennessee Rivers were analyzed for Ca, Sr, and Sr-90 to determine content of each as a function of species and location in the river, and whether Ca and Sr could be used as biological indicators of Sr-90 in the water. Calcium content of shells was relatively constant (40% of shell ash weight) as would be expected with calcium carbonate. Average Sr content of shells from different species of clams ranged from 156 to 382 mg/kg. Differences in Sr content are due to inherent differences between species rather than the Sr/Ca in the environment.

Two factors appear to affect Sr deposition in clam shells are growth rate and surface to volume relationships. The Sr content of shells increases with growth rate and with a reduced surface to volume ratio. These factors do not explain the Sr content of all species, and the inherent species differences may be related to the non-homogeneous distribution of Sr within the clam shells.

Probable reasons for the lower Sr/Ca ratios obtained in this study compared to ratios reported by others are differences in species and populations analyzed, environmental ratios, and errors in strontium determination. However, this is not an unequivocal explanation.

Low-level releases of Sr-90 were used as a tracer to determine the behavior of Sr-90 released to the Tennessee River system. There was a very good agreement between the Sr-90/Sr atom ratios observed and expected in clam shells on the basis of dilution of Clinch River water by Tennessee River water. This agreement suggests that clams may be used as samplers of Sr-90 and that Sr-90 released to the Clinch River is in equilibrium with the living and nonliving components of the river system. Concentrations of Sr-90 in the Tennessee River will be directly related to dilution of the contaminated water by noncontaminated water.

1034. Nelson, D.J. 1964. Interpretation of radionuclide uptake from aquatic environments. Nuclear Safety 5(2):196-199.

Equilibrium levels of radionuclides between aquatic organisms and environment are expected only for elements with a short biological half-life in tissue. The method of specific activities is based on the assumption that if the distribution of a stable element is known between an organism and its environment, it may be used to predict radionuclide concentrations in water organisms receiving constant radionuclide releases. The relation of strontium and strontium-90 in fish may be used to calculate expected body burdens. Specific activity relation might be a criterion for limiting radioactive waste disposal in oceans. While specific activity of a chemical element in environment of human food organisms is below the permissible limit for that element in a human body, man cannot obtain more than his permissible body burden from the seas. Direct application of the specific activity concept applies only to those radionuclides for which absorption is not critical, specific activities may be related to irradiation of the gastrointestinal tract by its contents.

1035. Nelson, D.M., G.P. Romberg, and W. Prepejchal. 1971. Radionuclides in Lake Michigan fish. In Report ANL-7860 (Pt.3), Radiological Physics Div. Ann. Report: 141-150.

In order to provide baseline data needed to evaluate any additional radioactive releases, fish samples were collected from Lake Michigan during 1970-1971 and analyzed for gamma emitting radionuclides. The Cs-137 content of bass, trout, and other fish species near the Big Rock Nuclear Reactor (a 70-MW boiling water reactor completed in 1962) was about double that near the Point Beach Nuclear Reactor (a 480-MW pressurized water reactor completed in 1970). The Cs-137/Cs-137 ratio was not high enough to support a recent station contribution of greater than 20% to the total Cs-137 concentration, except in a small number of bass and trout samples; however Zn-65 was detected, which is more straightforwardly attributable to the Big Rock station. A diet of 100 grams/day of fish with the highest radioactivity of those caught would contribute 0.3% of the maximum recommended daily intake.

1036. Nelson, J.D., W. Blair, F.E. Brinckman, R.R. Colwell, and W.P. Iverson. 1973. Biodegradation of phenylmercuric acetate by mercury-resistant bacteria. Appl. Microbiol. 26(3):321-326.

Selected cultures of mercury-resistant bacteria degrade the fungicide-slimicide phenylmercuric acetate. By means of a closed system incorporating a flameless atomic absorption spectrophotometer and a vapor phase chromatograph, it was demonstrated that elemental mercury vapor and benzene were products of phenylmercuric acetate degradation.

1037. Nelson, V.A. 1972. Effects of strontium-90+yttrium-90, zinc-65 and chromium-51 on the larvae of the Pacific oyster *Crassostrea gigas*. *In* Pruter, A.T., and D.L. Alverson (eds.). The Columbia River Estuary and Adjacent Ocean Waters, Bioenvironmental Studies. Univ. Washington Press, Seattle, Washington: 819-832.

Studies were undertaken to determine what concentration of radionuclides would affect oysters in the Willapa Bay, Wash. fishery. The production of abnormal larvae was selected as a measure of effects since this criterion has been equated with mortality in a study of effects of sulfite waste liquor. The radionuclide concentrations that increased abnormalities in oyster larvae (100 μCuries/l of Zn-65, 1000 μCuries/l of Sr-90, Y-90 and Cr-51) are one-million-fold greater than present in the environment.

1038. Nelson, V.A., and A.H. Seymour. 1974. Amchitka radiobiological program progress report. Univ. Washington Lab. Radiation Ecol., Seattle, Wash.: 1-98.

The Amchitka, Alaska, radiobiological program, to collect biological and environmental samples for radiometric analyses, began in 1970 and is continuing. Recent results of analyses have been appended to previously prepared tables and include analyses for: (1) gamma emmitting radionuclides of K, Co, Zr, Ru, Sb, Cs, Be, Eu, Mn, Nb, Ce and Zn in air filters, seawater, freshwater, birds, lichens, terrestrial vegetation, marine algae, marine invertebrates, (crustaceans, molluscs, echinoderms, sponges) marine fish, sea otter, aufwuchs, and freshwater moss and plants; (2) strontium-90 in rats and birds; and (3) tritium in seawater and freshwater.

The conclusions from the results of the recent analyses are a reiteration of previous results stated; namely, (1) no new radionuclides are present; (2) the most abundant radionuclides are naturally occurring beryllium-7 and potassium-40; (3) the trace quantities of fission products, induced radionuclides, and H-3 present are from world fallout; and (4) a trace of H-3 contamination remains in some Long Shot ponds, as previously reported. It is concluded from the results of analyses of samples collected between September 1968, and December 1973, as reported in this and the three previous progress reports, that there were no radionuclides of Milrow or Cannikin origin in the water, plants, or animals of Amchitka Island.

1039. Nicholls, G.D., H. Curl, Jr., and V.T. Bowen. 1959. Spectrographic analyses of marine plankton. Limnology and Oceanography 4:472-476.

The results of spectrographic analyses of ten species of zooplankton are presented. The methods used are described in detail. The elements determined quantitatively were boron, molybdenum, vanadium, nickel, cobalt, titanium, chromium, lead, tin, and copper. Manganese, cesium, rubidium, barium, strontium, and silver were detected in some or all of the specimens. Antimony, germanium, gallium, gold, and arsenic were sought for but not found. Cadmium was just detectable in only one species, the squid *Ommastrephes* (*Illex*) *illecebrosa*. The analytical results support the view that boron is actively concentrated or excluded by some marine animals. There is evidence that sedimentation of pteropod shells could be a major pathway for the removal of vanadium and lead from sea water. Lead was greatly enriched in *Centrophages*. Nickel and cobalt showed random variations with respect to one another.

1040. Nielsen, E.S., and L.Kamp-Nielsen. 1970. Influence of deleterious concentrations of copper on the growth of *Chlorella pyrenoidosa*. Physiologia Plantarum 23:828-840.

The effect of deleterious concentrations of ionic Cu on growth of *Chlorella pyrenoidosa* has been studied. An earlier paper showed a distinct effect of the same concentrations on photosynthesis. Several substances, e.g. Fe and citric acid, counteract the effect of Cu. In media ordinarily used for growing unicellular algae the influence of Cu is relatively slight due to the extraordinarily large concentrations of Fe. At a concentration of 6 μg/l Fe—near to that in nature—even one μg/l Cu significantly decreases growth during the first 24 hours. Cu is adsorbed to the negative charges on micelles of $Fe(OH)_3$ created in the alkaline medium. Citric acid is readily assimilated by *Chlorella* and thus counteracts the influence of Cu for only relatively short periods.

Cell concentration is of decisive importance for the deleterious influence of Cu on growth. The effect of a certain Cu concentration stops at a certain concentration of algae regardless of whether the experiment is started at this cell concentration or this level is attained during the experiment. This is due to the binding of Cu by the organic matter of cell walls and slime envelopes.

H^+ ions compete with Cu both when combining with organic matter in cell walls and when occupying active sites of cell membranes. The latter explains the fact that influence of Cu is only slight at pH 5 compared with that at pH 8. At a Cu-concentration where no growth of algae takes place, the algae are by no means killed. After being transferred to an ordinary medium algae start to grow again. The influence of Cu depends on the division stage of the algae. If the initial steps of cell division have taken place, the cell continues to divide.

1041. Nielsen, E.S., L. Kamp-Nielsen, and S. Wium-Andersen. 1969. The effect of deleterious concentrations of copper on the photosynthesis of Chlorella pyrenoidosa. Physiologia Plantarum 22(6):1121-1133.

This study, conducted under illuminated conditions, revealed that the maximum influence of copper sulfate on Chlorella pyrenoidosa is exerted during the first 24 hours of the plant's contact with the chemical. A significant depression of photosynthesis was observed at copper concentration as low as about 1 microgram/liter. A decrease of the medium reaction from pH 8 to pH 5 required a 10 times increase in copper concentration to obtain the same deleterious effect. Addition of potassium decreased the effectiveness of the herbicide and indicated that the eradicating effect of copper is not due to penetration of this ion into the plasma, but to a binding to the cytoplasmic membrane and arrested division of cells. Other cations tend also to displace copper from the active sites of the membranes.

1042. Nielsen, E.S., and S. Wium-Andersen. 1970. Copper ions as poison in the sea and in freshwater. Marine Biology 6(2): 93-97.

Copper in ionic form is found to be very toxic to photosynthesis and growth of unicellular algae at concentrations usually found in natural waters, indicating that copper is not ordinarily present in ionic form but is complexed by organic matter such as polypeptides. The affinity of copper to diethyl-dithiocarbaminate is very much higher than to the organic matter which completes copper in nature, thus it is not possible to distinguish the two forms of copper during analysis. Complexed copper is not poisonous to algae. It has recently been shown that ocean water in the centers of upwelling becomes suitable for plankton growth only after the addition of a chelator, suggesting that a large part of the copper found in subsurface waters of oceans is present in ionic form. Some manufacturers of Carbon-14 ampules have used ordinary distilled water which often has a content of about 250 micrograms copper per liter; thus, it is probable that some productivity measurements have been influenced.

1043. North, W.J., G.C. Stephans, and B.B. North. 1972. Marine algae and their relations to pollution problems. In Ruivo, M. (ed.). Marine Pollution and Sea Life. Fishing Trading News (books) Ltd., London: 330-340.

Known toxicants and depressants for marine algae include heavy metals (Cr, Cu, Hg, Ni, Pb, Zn), simple organics (benzene, cresol, hexane, phenol, toluene), various inorganics (Cl, CN, H_2S), and complex wastes (industrial sewage, sulfite waste liquor, petroleum compounds, detergents). Toxicity determinations using freshwater algae suggest that many additional substances could influence marine algae. Stimulatory substances occurring significantly in certain wastes include phosphate, nitrogen as ammonia, nitrate, and organic nitrogen, and silica. P/N ratios and concentrations of various forms of P and N may affect species composition as well as productivity. Comparisons of organic nitrogen (as amino acids) uptake rates by "pollution" algae (Ulva, Enteromorpha) vs. other forms (18 macrophytes, 12 microphytes) offer an experimental basis to explain success of certain algae in organic-rich environments. Conversely some algae secrete organics copiously which might stimulate growth in certain animals.

1044. Noshkin, V.E. 1972. Ecological aspects of plutonium dissemination in aquatic environments. Health Physics 22:537-549.

Increased utilization of transuranics in the nuclear industry creates a need to understand their biogeochemical behavior in the aquatic environment. This review considers some documented sources which contribute transuranics to the aquatic environment and particularly the ecological aspects of plutonium. Most plutonium-239 present in the environment has originated from both underwater and atmospheric nuclear tests. Quantities of transuranics were deposited in discrete marine environments near "surface and underwater burst" test sites; they are detected in the vicinity of fuel reprocessing facilities, are introduced to aquatic environments from accidents involving nuclear devices, and from laboratories involved in nuclear production or fabrication. Plutonium is highly concentrated by a number of marine species. To evaluate uptake and retention of plutonium in sediments, their lithological and chemical differences, type and organic content, and biological activity must be considered. Bone and liver are major repositories for plutonium in marine vertebrates while muscle tissue of both marine vertebrates and invertebrates contain relatively lower concentrations. When the relative biological effectiveness of alpha vs. gamma or beta radiation is considered, fallout plutonium-239 contributes more than fallout strontium-90 or cesium-137 to artificial radiation exposure of many marine species.

1045. Nuorteva, P., and E. Häsänen. 1971. Observations on the mercury content of Myoxocephalus quadricornis (L.) (Teleostei, Cottidae) in Finland. Ann. Zool. Fennici 8:331-335.

Mercury content was determined in the fourhorn sculpin, a glacial relict occurring in the Baltic and in some lakes. In an unpolluted area of the Baltic, mercury content varied between 0.06-0.36 mg/kg, being positively correlated with size. In stunted specimens of Lake Ladoga, Hg content was the same as in the largest specimens in the Baltic—probably because their ages were identical and hence also the possibility for bioaccumulation. In the mercury-polluted Lake Päijänne, mercury content of M. quadricornis was elevated, values up to 1.9 mg/kg being found. In another lake, Näsijärvi, with the same degree of mercury pollution, however, mercury contamination of M. quadricornis was very low (0.02-0.28 mg/kg), possibly because the oxygen content of its deeps is so low that mercury is not microbially transformed to the bioaccumulating methylmercury.

1046. Nuorteva, P., and E. Häsänen. 1972. Transfer of mercury from fishes to sarcosaprophagous flies. Ann. Zool. Fennici 9:23-27.

Sarcosaprophagous flies were reared from eggs to adults on fish containing 0.14, 0.17, 0.47 and 1.90 mg/kg of mercury. The transfer of mercury from the food to the larvae was followed by activation analysis. When fed on fish of the two lowest ("natural") levels of mercury, fly larvae had the same mercury content as their food. With a mercury content of 0.47 mg/kg in fish, the full-grown fly larvae had 0.62 mg/kg. But with a mercury level of 1.90 mg/kg in fish, full-grown larvae contained 6.90 mg/kg, which is a clear indication of bioaccumulation. It is suggested that fly larvae are capable of inhibiting bioaccumulation of mercury only if it is present in the food in "normal" concentrations. When, for a short period the larvae were given mercury-contaminated (9.07-10.62 mg/kg) adult flies as food their mercury content rose from low level to 11.40 mg/kg. Because of the weight loss caused by evaporation and respiration during the pupal stage, the mercury content of the adult flies was about 1 1/2 times as high as that of the full-grown larvae. Free-living fly populations in general had low mercury contents (0.02-0.06 mg/kg), except for one sample (0.50 mg/kg) collected on the shore of a mercury-polluted lake at a place where fish are regularly cleaned.

1047. Nuzzi, R. 1972. Toxicity of mercury to phytoplankton. Nature 237(5349):38-40.

Mercury, as phenylmercuric acetate (PMA), was found to be inhibitory to three phytoplankton species at concentrations as low as 0.06 µg/l.

1048. Ogata, E., and W. Schramm. 1971. Some observations on the influence of salinity on growth and photosynthesis in Porphyra umbilicalis. Marine Biology 10:70-76.

Rate of growth and O_2 output of the intertidal red alga Porphyra umbilicalis from Helgoland, North Sea, were measured during a 3 week culture in 3 different salinities (1/2, 1- and 2-concentrated artificial seawater). Under hypertonic conditions (2 concentrated seawater) growth rate and phytosynthesis rate were depressed, compared to values obtained in normal concentrated seawater. Under hypotonic conditions (1/2-concentrated seawater), growth expressed in mg was the same as in normal concentrated seawater, or higher when expressed in cm^2. Rate of O_2 output was almost unaltered in one of the two experiments, lowered in the other. Cell size increased at higher salinity, while swelling of cell walls and intercellular substances as well as the intensity of coloring decreased with salinity. The discrepancies between growth and phytosynthesis under hypotonic conditions cannot be completely explained by the observed influences of salinity on morphological structures (cell size, swelling of cell substances).

1049. O'Hara, J. 1971. Alterations in oxygen consumption by bluegills exposed to sublethal treatment with copper. Water Research 5:321-327.

Oxygen consumption rates were determined for juvenile bluegill sunfish subjected to various concentrations of copper. Respiratory responses were strongly correlated with copper concentrations up to the LC-50 (96 h) value of 2.4 mg/l of copper. Higher concentrations produced greater responses although the results were more erratic. The concentration that caused no alteration in the rate of oxygen consumption was found to be 0.1 mg/l of copper. It is suggested that this measure provides a fast and sensitive tool to help establish water quality criteria.

1050. O'Hara, J. 1973. Cadmium uptake by fiddler crabs exposed to temperature and salinity stress. Jour. Fish. Res. Bd. Canada 30(6):846-848.

Fiddler crabs (Uca pugilator) were collected from an unpolluted estuary near Georgetown, South Carolina, and, after acclimation, subjected to 1 microcurie of Cd-109 and 10 μg/l Cd^{2+} as cadmium chloride in 3, 10, and 25°C vs. 10 and 30‰ salinity. After 24, 48, and 72 hours, samples were sacrificed and gill and hepatopancreas analyzed for Cd. At each temperature crabs accumulated more Cd in low salinity water than in high salinity water. This effect is probably due to osmotic stress caused by the different salt concentrations. Maximum accumulations occurred at high temperature and low salinity with totals for gill and hepatopancreas of 65 and 74 mg/kg at 24 hr, 98 and 198 mg/kg at 48 hr and 92 and 200 mg/kg, respectively, at 72 hr.

1051. O'Hara, J. 1973. The influence of temperature and salinity on the toxicity of cadmium to the fiddler crab, Uca pugilator. U.S. Dept. Comm., Fish. Bull. 71(1):149-153.

The concentrations of cadmium lethal to fiddler crab were determined for various environmental regimes of temperature and salinity. Mortality was greatest in high temperatures and low salinities when tested for 240 hr. The LC-50 (240 hr) value at 30°C and 10‰ salinity—the most pronounced thermosaline regime tested—was 2.9 mg/l of Cd^{2+}. Concentrations of cadmium were greatest in green gland followed by gill, hepatopancreas and muscle.

1052. Olson, K.R., H.L. Bergman, and P.O. Fromm. 1973. Uptake of methyl mercuric chloride and mercuric chloride by trout: a study of uptake pathways into the whole animal and uptake by erythrocytes in vitro. Jour. Fish. Res. Bd. Canada 30:1293-1299.

Uptake rate of either $^{203}HgCl_2$ or $CH_3{}^{203}HgCl$ by rainbow trout (Salmo gairdneri) was not affected by esophageal ligation during a 24 hr period. Uptake of these two mercurials in nonfeeding trout appears to be via the gills. Methylmercury enters fish at a faster rate than the inorganic form and anomalous tissue distribution of these two mercurials suggests that inorganic mercury does not require methylation prior to entry into the fish. In vitro experiments using radioactive mercurials demonstrated high affinity of methylmercury for red cells (up to 90% was bound to red cells in 40 min). Only 9% of inorganic mercury was taken up by red cells, but, this percentage was increased up to 65% of the cells were washed and suspended in Ringer solution prior to incubation with mercury.

1053. Olson, K.R., and P.O. Fromm. 1973. Mercury uptake and ion distribution in gills of rainbow trout (Salmo gairdneri): tissue scans with an electron microprobe. Jour. Fish. Res. Bd. Canada 30(10):1575-1578.

Rainbow trout were exposed to 0.25 mg/l of $HgCl_2$ and 0.05 mg/l methylmercury for 23 hr and the gills removed and examined by electron microprobe for the purpose of identifying pathway of Hg uptake. Mercury was found in gills of rainbow trout which had been exposed to inorganic mercury but not in those exposed to methylmercury. No specific site for mercury uptake was identified and it is suggested that inorganic mercury enters the gill across the general lamellar surface. High concentrations were found associated with the gill cartilage. Since little ion diffusion occurs during tissue preparation, localization and/or identification of tissues can be accomplished by scans for various elements: sodium (Na), potassium (K), chlorine (Cl), and sulfur (S). The technique is not suitable for identification of highly volatile compounds such as methylmercury due to the necessity of subjecting tissues to high vacuum conditions, however, electron probe analyses should be useful in studies of active ion transport systems in gill tissue and in investigations of the effects of heavy metal pollutants on fishes.

1054. Olson, P.R. 1971. Accumulation of calcium-45 in developing coho salmon eggs and fry reared in varying concentrations of stable calcium. From Sel. Water Resources Abstracts, 1972. 5(15):66.

Coho salmon eggs were fertilized and reared in tap water with calcium concentrations of 6 to 76 mg/l, labelled with Ca-45, to study the effect of this cation on embryo development and hatching. Fertility of eggs was improved in calcium concentrations above 6 mg/l. Eggs in calcium concentrations of 76 mg/l hatched two days earlier than those in solutions containing 6 mg/l. The stable calcium concentration in all lots was similar, regardless of calcium concentrations in the solutions. A significant amount of calcium-45 entered the eggs during the water-hardening period, but only a slight amount was taken up during the 57 days to hatching. During the two week period after hatching, a tenfold increase in the uptake of calcium-45 was noted, which was associated with ossification. Discussion is also included on the concentration of stable calcium, magnesium, sodium, and potassium in the fry of different species of fish.

1055. Ophel, I.L. 1963. The fate of radiostrontium in a freshwater community. In Schultz, N., and A.W. Klement, Jr. (eds.). Radioecology. Reinhold Publ. Corp., New York: 213-216.

Strontium-90 has been followed through a stream-fed ecosystem containing dissolved radionuclides from seeps in a liquid disposal area of the Canadian Atomic Energy Establishment. Amounts entering Perch Lake during five years and leaving by an outlet stream were measured. Strontium-90 content in the bones of adult perch (fish) increased gradually over a four-year period, reaching equilibrium the fifth year. Most of accumulated radiostrontium is retained in the skeleton and a considerable fraction in adult fish bone is non-exchangeable. When the concentration factor for perch flesh is only five, that for bone is 3,000. Transmission of radiostrontium and radiocesium can be compared thus: for water containing the (then) maximum permissible concentration of cesium-137, maximum permissible body burden of Cs-137 for man would be contained in 20 grams of fish flesh, while maximum permissible body burden of Sr-90 would be contained in 100 kilograms of perch flesh. It would seem, therefore, that the major pathway of radiostrontium—in contrast to radiocesium—to man from a contaminated body of water would be from direct use of water for drinking, rather than by way of food webs originating in the aquatic environment.

1056. Ophel, I.L. 1973. The environmental capacity of freshwaters for waste radionuclides. In Environmental Behavior of Radionuclides Released in the Industry. Int. Atom. Ener. Agen., Vienna, Austria: 613-624.

The maximum permissible human body burden of many radionuclides can be expressed as a specific activity, i.e. the amount of a radioisotope per unit weight of its stable counterpart. A similar concept can be applied to a large body of water that is providing water and food for man. It can be thought of as a pool or reservoir of stable elements that could dilute waste radionuclides down to specific activities less than those corresponding to the body burden. It is the size and the dynamics of this stable element pool that determine the environmental capacity of an aquatic ecosystem for a radionuclide.

Results from a continuing study of strontium in an experimental lake (Perch Lake, Ontario) illustrate some of the factors that must be considered. Using elevated levels of Sr-90, which have been present in the lake since 1955, it has been possible to investigate the dimensions and the dynamics of the various compartments that make up the stable strontium pool. Several of these compartments, such as lake water and some biota, have a fast turnover time (i.e. they rapidly attain a uniform specific activity); but they make up only a small fraction of the stable element pool. Other compartments of interest are the marginal vegetation and the semi-aquatic animals, which cause a carry-over of Sr-90 into terrestrial food-chains and result in further dilution of the radionuclide. Bottom sediment is important, although a considerable fraction of the stable strontium in the sediment of Perch Lake has such a slow exchange with the lake water that it limits the effective size of this compartment. However, it is the trapping action of the sediment and the consequent removal of some radionuclides from the ecosystem that provide the continuing capacity of a lake to accept such radionuclides.

1057. Ophel, I.L., and C.D. Fraser. 1971. The fate of cobalt-60 in a natural freshwater ecosystem. In Radionuclides in Ecosystems (Proc. Third Nat. Symp. Radioecol., May, 1971):323-327.

Perch Lake is a small dystrophic-eutrophic lake on the property of Atomic Energy of Canada Limited at Chalk River, Ontario. For seven years it has been receiving at a relatively constant rate small amounts of Co-60 via its inlet stream, resulting in low, but measurable concentrations of this radionuclide in the lake water. Concentration factors were determined for the dominant species of aquatic plants, fish, and other biota. Large differences in accumulation were found between species of plants due to morphology of the plants and their location in the lake. Differences between fish species are correlated with their feeding habits. The vertical and horizontal distribution of radiocobalt in the bottom sediments was investigated. Most of the nuclide is confined to the upper few centimeters of the organic-rich deposits. Calculations indicate that the lake sediment is an important storehouse of cobalt and that approximately 30% of the Co-60 that has entered the lake is now resident on the bottom.

1058. Ophel, I.L., C.D. Fraser, and J.M. Judd. 1971. Strontium concentration factors in biota and bottom sediments of a freshwater lake. In Proc. Int. Symp. Radioecology App. Prot. Man and his Environ., Rome, 7-10 Sept. 1971:510-530.

Over a period of years concentration factors were determined of both stable and radioactive strontium in bottom sediments and biota of a lake chronically contaminated with low levels of Sr-90 from radioactive wastes. Concentration factors (on a fresh weight basis) in six species of fish range from 450 to 1250; in 22 species of aquatic plants from 30 to 1300. Each species exhibits a characteristic concentration of the element. The strontium content of bottom sediments is strongly correlated with the amount of organic matter they contain. The specific activity of the strontium (dpm Sr-90/μg Sr) appears to be uniform throughout the water and the lake biota, i.e. biological availability of the stable isotope and radioisotope is the same. In the upper 10 cm of bottom sediments however, specific activity of the exchangeable strontium and of total strontium is only half that in biota and water indicating incomplete exchange of radionuclide and stable element in this layer even after fifteen years of exposure.

1059. Oseid, D., and L.L. Smith, Jr. 1972. Swimming endurance and resistance to copper and malathion of bluegills treated by long-term exposure to sublethal levels of hydrogen sulfide. Trans. Amer. Fish. Soc. 101(4):620-625.

After 126 or 148 days of exposure to H_2S concentrations ranging from 0.0004 to 0.0146 mg/l, young-of-the-year bluegills were tested for swimming endurance and resistance to copper or malathion. Swimming tests at low speeds indicated increased endurance for fish exposed to 0.0004 mg/l H_2S but fish exposed to higher concentrations had progressively less endurance than the controls. In the tests conducted at higher speeds, fish in all test concentrations showed less endurance than the controls. Resistance to copper was increased by exposure to H_2S, but resistance to malathion was not affected except in the lowest test concentration. The chronic exposure to H_2S also reduced growth in the highest concentration, and gill irrigation rate increased progressively with increased concentrations.

1060. Osterberg, C., J. Pattullo, and W. Pearcy. 1964. Zinc 65 in euphausiids as related to Columbia River water off the Oregon coast. Limnology and Oceanography 9(2):249-257.

Most of the zinc-65 in the northeast Pacific Ocean originates in the Columbia River as a result of the Hanford, Washington, nuclear reactor operation. The Columbia River is also the principal source of freshwater in the region. At certain seasons the plume of the river is detectable far at sea because of its low salinity. In an effort to determine the fate of the river water at sea, euphausiids from the ocean off Oregon were used as biological monitors. Zn-65 content of euphausiids was measured and relationships between Zn-65 content and salinity distributions over the area examined. Zn-65 levels remained fairly high off Oregon even when Columbia River water was not evident as a low-salinity plume. This indicates that water from the Columbia River, which accumulates as a plume off Oregon in the summer, influences Zn-65 content in animals in the area throughout the year. The long half-life of Zn-65 in the mixed layer, diurnal migrations of euphausiids, and seasonal reversal of currents all may contribute to the maintenance of this reservoir of Zn-65 in the ocean off the Oregon coast.

1061. Paasche, E. 1973. Silicon and the ecology of marine plankton diatoms. I. _Thalassiosira pseudonana_ (_Cyclotella nana_) grown in a chemostat with silicate as limiting nutrient. Marine Biology 19(2):117-126.

Silica content of diatom shells varied with growth rate. As growth rate approached zero, there were still measurable quantities of residual reactive silicate in the medium. In one of the two chemostats used, silicate assimilation by cells was inefficient due to some unknown internal or external factor. In the other chemostat, statistically calculated half-saturation constants of growth rate were in the range of 0.5 to 0.8 microgram at. Si/l. Half-saturation constants of steady-state mean silicate uptake per cell and hour, calculated in a similar fashion, were in the range of 1.4 to 2.6 microgram at. Si/l. Results indicate that silicate concentrations causing a reduced silicate uptake by this species in nature do not necessarily result in a corresponding reduced growth rate. Growth in coastal waters is likely to become seriously limited by a shortage of silicate only when most of the silicate originally present has been removed in the course of a diatom bloom.

1062. Paasche, E. 1973. Silicon and the ecology of marine plankton diatoms. II. Silicate-uptake kinetics in five diatom species. Marine Biology 19:262-269.

Variations in rate of silicate uptake with varying silicate concentration in the medium was investigated in short-term experiments with the following marine diatom species: Skeletonema costatum, Thalassiosira pseudonana, T. decipiens, Ditylum brightwellii and Licmophora sp. The uptake conformed to Michaelis-Menten kinetics only after a correction had been made for reactive silicate that apparently could not be utilized by diatoms. The magnitude of this correction was in the range of 0.3 to 1.3 μg at. Si/l. Mean values of the half-saturation constant of silicate uptake were calculated for the different species. The lowest value found in S. costatum (0.80 μg at. Si/l) and the highest in T. decipiens (3.37 μg at. Si/l). Growth limitation by low silicate concentrations could be a cause of species succession in marine plankton-diatom blooms.

1063. Paffenhoefer, G.A. 1972. The effects of suspended "red mud" on mortality, body weight, and growth of the marine planktonic copepod, Calanus helgolandicus. Water, Air, and Soil Pollution 1(3):314-321.

"Red mud" is the residual substance after the extraction of aluminum from bauxite; it is a waste product associated with aluminum production. The effects of red mud on growth, body weight and mortality of the copepod Calanus helgolandicus were investigated. Laboratory tests were conducted using copepods which ingested large quantities of red mud and control groups. Growth of the experimental copepods was delayed in comparison to controls; the red mud group also had a higher mortality rate than controls. The small amount of phytoplankton present in red mud weakens the animals; although they ingest large quantities of mud, they were unable to attain a sufficient amount of nutritive material. Adult copepods in the red mud group exhibited sluggish swimming movements and slow reactions which would make them easy prey for predators. The study concludes that the proposed dumping of red muds into the North Sea will create a serious problem in the nutrition, survival, and reproduction of planktonic copepods.

1064. Pagenkopf, G.K., R.C. Russo, and R.V. Thurston. 1974. Effect of complexation on toxicity of copper to fishes. Jour. Fish. Res. Bd. Canada 31:462-465.

Copper is highly complexed by carbonate and hydroxide ions in natural waters and this complexation determines the concentration of copper species in solution. Results of detailed equilibrium calculations on data from bioassays where alkalinity, pH, hardness and total copper concentration are different indicate that copper (II) is the chemical species that is toxic to fishes and that alkalinity is the factor controlling copper (II) concentration.

1065. Pakkala, I.S., W.H. Gutenmann, D.J. Lisk, G.E. Burdick, and E.J. Harris. 1972. A survey of the selenium content of fish from 49 New York State waters. Pesticides Monitoring Jour. 6(2): 107-114.

A survey was made of the selenium content of 438 fish of various species collected in 1969 from 49 New York State waters and a group of lake trout sampled in 1970 from Cayuga Lake only. Concentrations of selenium in decapitated, eviscerated fish on a freshweight basis were usually below 1 mg/kg. There was little apparent correlation between selenium concentrations and species or sampling locations except that sturgeon from the Hudson River, lake trout from Lakes George and West Canada, whitefish from Raquette Lake, and several species from Lake Pleasant had consistently higher levels of selenium than other samples; all fish from Lakes Butterfield and Champlain and the Chenango and Salmon Rivers had consistently lower levels. No correlation was apparent between selenium levels and size or sex of fish. Selenium did not appear to be cumulative in lake trout of known age up to 12 years from Cayuga Lake.

1066. Pakkala, I.S., M.N. White, G.E. Burdick, E.J. Harris, and D.J. Lisk. 1972. Residues in fish, wildlife, and estuaries. A survey of lead content of fish from 49 New York State Waters. Pesticides Monitoring Jour. 5(4):348-355.

A survey was made of 419 fish in 49 New York State waters for total lead content and compared to data presented on a series of lake trout sampled in 1970 from Cayuga Lake in order to determine if lead was cumulative in these fish. Results showed that lead concentrations usually ranged from 0.3 to 1.5 mg/kg, and a few samples up to 3.0 mg/kg. Variations were found in lead content of fish taken from different lakes, but no correlation was observed between lead concentration and size, species, or sex. Lead did not appear to be cumulative in lake trout up to 12 years of age taken from Cayuga Lake.

1067. Pakkala, I.S., M.N. White, D.J. Lisk, G.E. Burdick, and E.J. Harris. 1972. Arsenic content of fish from New York State waters. N.Y. Fish Game Jour. 19(1):13-31.

A survey of 471 fish sampled in 1969 from 49 New York State waters for total arsenic content is presented. Arsenic levels ranged up to about 0.5 mg/kg with fish from Lake Ontario, Canandaigua Lake and the Hudson, St. Lawrence and Salmon Rivers being relatively higher. Larger fish generally contained higher arsenic concentrations. Arsenic did not appear to be cumulative with increasing age in lake trout ranging from 2 to 11 years old.

1068. Palmer, D.S., and L.J. Albright. 1970. Salinity effects on the maximum hydrostatic pressure for growth of the marine psychrophilic bacterium, *Vibrio marinus*. Limnology and Oceanography 15(3):343-347.

In nondefined basal medium containing 35^{o}/oo synthetic seawater salts, *Vibrio marinus* reproduces at hydrostatic pressures of 422 and 280 atm at 9 and 4°C respectively; in defined basal medium containing 35^{o}/oo NaCl, these maximums are 422 and 327 atm at 9 and 4°C. Decreasing the NaCl concentration results in a corresponding decrease in the maximum hydrostatic pressure at which these cells divide: at 8^{o}/oo NaCl, cell division is inhibited above 88 and 61 atm at 9 and 4°C. The relative order of effectiveness for the substitution of the Na^+ requirement in a defined basal medium containing 8^{o}/oo NaCl is $Na^+ > K^+ > NH_4^+$. The relative order of effectiveness for the substitution of the Cl^- requirement, in the same basal medium, is SO_4^{2-}, PO_4^{3-}, $Cl^- > Br^- > NO_3^-$. The relative ranking of these ions depends on the NaCl content of the basal medium.

1069. Pappas, C.J., O.W. Tiemeier, and C.W. Deyoe. 1973. Chromic sesquioxide as an indicator in digestion studies on channel catfish. Progr. Fish-Cult. 35(2):97-98.

Chromic sesquioxide was used in feed to indicate digestion and absorption of protein, fat, and nitrogen-free extract (NFE) by channel catfish, *Ictalurus punctatus*. Results indicated that absorption of protein, fat, and NFE starts in the stomach within 2 hours; by 4 hours nearly 50% of the available nutrients had been absorbed. By 6 hours most of the feed had passed into the intestine where further digestion and absorption took place. Absorption values in the intestine reached 80% after 8 hours. The results from this preliminary study indicate that Cr_2O_3 and the indicator did not appear to affect digestion.

1070. Parchevskii, V.P., L.G. Kulebakina, I.A. Sokolova, and A.A. Bachurin. 1970. Sr90 in aquatic organisms of the Black Sea. Available from Nat. Tech. Inf. Ser., Springfield, Va., as part of AEC-tr-7299. Translation of Morskaya Radioekologiya (Marine Radioecology):196-221.

Studies in 1965-1966 showed low variability in Sr-90 uptake within the same species. Of total Sr-90 in plant communities and in surrounding water, the percentage absorbed by plants varied according to species (*Cystoseira* brown alga, 30%; *Carallia* red alga, 23%; *Padera* brown alga, 17%; *Zostera* flowering plant, 11%; other algae, 1%; *Cystoseira biocoenosis* that includes animals and other plants, 40%). For *Cystoseira* samples in Sept. 1964 and Dec. 1965, Sr-90 concentration was about twice as high in the stem as in the branches; but in July 1965 there was no difference (a seasonal effect). Sr/Ca atomic ratios were nearly the same in organisms from related taxonomic groups and agreed with values obtained by others. Isotopic exchange between Sr-90 and Sr was nearly complete.

1071. Parchevskii, V.P., I.A. Sokolova, G.G. Polikarpov, and A.A. Bachurin. 1970. Radiobiological research in oceans and generalizations in marine radioecology. Available from Nat. Tech. Inf. Ser., Springfield, Va., as part of AEC-tr-7299. Translation of Morskaya Radioekologiya (Marine Radioecology): 292-324.

When isotopic or non-isotopic carriers remain constant, radionuclide uptake by aquatic organisms is given by concentration factors (ratio of radioactivity of organism to that of an equal weight of water) which are independent of the radionuclide concentration in the water in the range 1-100 micromoles/liter. Sr-90 uptake by related organisms is about 2-fold higher in the Black Sea than in most other oceans or seas which have lower Ca content. Uptake of Cs-137, Sr-90, and S-35 is about an order of magnitude higher in fresh water than in sea water, corresponding to the higher carrier content of sea water. Data obtained during 1961-1966 on Sr-90 in marine organisms (in units of picoCuries/kg) is reviewed. Values for various species of fish ranged from 1 to 10. Pollution by nuclear wastes caused higher values for brown algae in the Irish Sea (10-600) than in most other seas and oceans (1-3).

1072. Parry, G.D.R., and J. Hayward. 1973. The uptake of ^{65}Zn by Dunaliella tertiolecta Butcher. Jour. Mar. Biol. Assn. U.K. 53:915-922.

Laboratory experiments were conducted to examine uptake of Zn-65 by the alga Dunaliella tertiolecta, specifically to investigate processes involved, and factors affecting uptake and its relationship to metabolism. The uptake of Zn-65 was temperature and pH dependent and appears to be indirectly linked with metabolism. The Zn-65 is firmly bound to living cells and it is suggested that the binding sites are proteinaceous compounds.

1073. Parslow, J.L.F. 1973. Mercury in waders from the Wash. Environ. Pollut. 5:295-304.

Concentrations of total mercury were determined in livers of seventy-three waders (Limicolae) collected during August-March on the Wash, eastern England, in order to obtain baseline data on levels of this element in birds living in a non-industrial and presumably lightly polluted estuarine area. In the knot (Calidris canutus), mercury levels were relatively low, about 1 mg/kg dry weight, in early autumn but increased through the winter until, by February-March, they were about 10-20 times higher. On more limited or scattered data, the dunlin (C. alpina) and redshank (Tringa totanus) also showed much higher mercury levels in late winter compared with autumn. The results imply that mercury accumulated in liver during the winter months (when the birds are exclusively estuarine, mainly in temperate latitudes) is eliminated in summer (on mainly inland arctic and subarctic breeding grounds). The results are discussed in relation to the molt, movements and food of the main species. The biological significance of the concentrations found in the Wash waders is uncertain, but it is suggested that in industrial estuaries mercury levels in the same species may be very much higher and, by analogy with other species, could be having detrimental physiological effects.

1074. Parslow, J.L.F., D.J. Jefferies, and H.M. Hanson. 1973. Gannet mortality incidents in 1972. Marine Pollution Bull. 4(3): 41-43.

Investigations of 2 incidents in 1972 on the east and west coasts of Britain involving the death of unusually large numbers of gannets (Sula bassana) indicated that they were not related. Concentrations of polychlorinated biphenyls were much higher in livers of birds from the west coast and may possibly have contributed to their death. One of these birds also contained an exceptionally high level of liver Hg.

1075. Parsons, T.R., C.A. Bawden, and W.A. Heath. 1973. Preliminary survey of mercury and other metals contained in animals from the Fraser River mudflats. Jour. Fish. Res. Bd. Canada 30(7): 1014-1016.

Additional research has been directed toward answering the question of the source of mercury contamination in the Fraser River estuary. The Fraser River mudflat community was divided into two areas from which crabs were collected for Hg analysis. Crabs and other marine organisms were also collected from other areas for comparative analyses. Samples of soft tissue were analyzed by atomic absorption spectrophotometry for Ag, Cd, Co, Cu, Mn, Ni, and Zn. However, Pb analysis was done colorimetrically and Hg was analyzed by flameless atomic absorption. Benthic animals from Sturgeon Bank contained larger amounts of mercury and other metals than animals from similar environments on the coast of British Columbia. These high levels of metals are believed to be associated with the Vancouver City sewer outfall.

1076. Patel, B., P.M.A. Bhattathiri, and G.R. Doshi. 1966. Uptake of manganese-54 by ark-shell mollusc, Anadara granosa (Linn). Jour. Anim. Morphol. Physiol. 13:158-168.

Studies were conducted on uptake, loss and retention of Mn-54 by the ark-shell mollusc Anadara granosa under laboratory conditions. Soft tissues reached apparent equilibrium in 3-4 days of exposure. Gills and mantle folds showed maximum concentration of Mn-54 followed by shell and other soft tissues.

The rate of uptake of Mn-54 was a function of body weight, with lower values for smaller animals. On return to isotope-free medium, gills lost activity rather rapidly. Shell retained the most and the gills the least amount of Mn-54 after 15 days. Concentrations of stable Mn, Zn, K, and gross beta activity were also weight dependent. The mantle folds and the gills showed maximum concentration of zinc and manganese.

Chronic concentration factors for Mn and Zn in A. granosa were significantly higher than acute concentration factors obtained using isotopes under laboratory conditions.

1077. Patel, B., and A.K. Ganguly. 1973. Occurrence of Se 75 and Sn 113 in oysters. Health Physics 24:559-562.

The specificity of various species of molluscs in the vicinity of the Tarapur nuclear powerplant for various radionuclides suggested their use as biological monitors. Gastropods (*Aplysia benedicti*, *Cellana radiata*, and *Onchidium verruculatum*) concentrated Co radioisotopes; oysters (*Crassostrea cucullata* and *C. gryphoides*) concentrated Sn-113 and Se-75, which were identified by the energy of gamma spectrum lines and half-lives; but not Co. The Sn-113 probably results from neutron activation of Sn-112 (isotopic abundance 0.95%) in fuel cladding and structural alloys; the Se-75, from neutron activation of Se-74 of unknown origin or as a fission product. Concentrations that have been reported in marine organisms are: Sn, 0.2 to 20 mg/kg; Se, 0.5 to 8.6 mg/kg.

1078. Patel, B., P.G. Valanju, C.D. Mulay, M.C. Balani, and S. Patel. 1973. Radioecology of certain molluscs in Indian coastal waters. *In* Radioactive Contamination of the Marine Environment. Int. Atom. Ener. Agen., Vienna, Austria: 307-330.

Distribution of a few major and trace elements of metabolic significance in the sea-hare *Aplysia benedicti* (mollusc), which moves shorewards in coastal waters during colder months, are presented. The population was found to accumulate trace elements belonging to iron family (atomic Nos. 23-28). Of the various tissues analyzed, the hepatopancreas and intestine including the gut-content showed higher concentrations of Co, Fe and Ni, whereas Fe was deposited in buccal mass. The bio-accumulation of Zn, Cu, Sr and Ca in whole animal and various tissues is also discussed in relation to environment. The *Aplysia benedicti* population from Tarapur waters which receive radioactive wastes (I-131, Cs-137, Cr-51, Co-58,60, Mn-54, etc.) from a boiling-water reactor, was found to accumulate Co-58 and Co-60 in the soft tissues. Hepatopancreas and gut-content contained the highest concentration of radiocobalt. Iodine-131, on the other hand, was concentrated in horny internal shell, possibly as a means for disposal. The spawn chords of this species were also found to accumulate I-131 from the environment. This species could therefore be used as an indicator of radionuclides of cobalt, although its occurrence in nearshore waters is strictly seasonal.

1079. Paterson, R.A., and D.F. Farr. 1973. Aquatic fungi of the lotic environment and their role in stream purification. Virginia Water Res. Research Cen., Blacksbury, Completion Report, OWRR A-043-Va(1):1-40. Available from the Nat. Tech. Inf. Ser. as PB-220 012.

Samples were collected from three rivers and streams of varying physical and chemical characteristics and subsequently examined for aquatic Phycomycetes. Three species of fungi were found in all samples collected. The filamentous forms such as Achlya, Saprolegnia, and Pythium were abundant in all three rivers. However, the unicellular forms such as Rhizophydium and Phlyctochytrium were infrequently encountered or absent in the eutrophic river but very common in the oligotrophic situations. Samples collected immediately below the introduction of the effluent from an army ammunition plant showed a greatly reduced flora of aquatic Phycomycetes. Achlya flagellata, a Rhizidium sp. and a Phlyctochytrium sp. were isolated from natural collections and their responses in terms of growth and reproduction to zinc, mannitol, cyanide, and surfactants were observed. These studies showed the filamentous form, Achlya flagellata, to be more tolerant to the toxic effects of these chemicals than were the unicellular Phlyctochytrium and Rhizidium.

1080. Peakall, D.B., and R.J. Lovett. 1972. Mercury: its occurrence and effects in the ecosystem. BioScience 22(1):20-25.

Preliminary reports indicate that levels in marine fish have not increased in recent years. The levels found in tuna and swordfish are likely natural levels caused by their predatory nature and longevity. This conclusion is in line with the fact that the amount released annually by man is about 10^4 tons compared to 10^8 tons present in the ocean. Thus, without some subtle concentration mechanisms, man's activities cannot appreciably alter the levels in the total ocean. The direct human health hazard of environmental mercury appears to be limited to those persons for whom fish is a dominant part of their diet. The concentration of mercury in the aquatic food-chain combined with transformation into methylmercury are the causative factors in this problem. The finding of increased chromosome breakage associated with elevated levels of blood in persons eating fish regularly (levels in fish were probably 1-17 mg/kg) and concentration across the placenta suggests that the currently accepted level of 0.5 mg/kg does not have an appreciable margin of safety for pregnant women. For wildlife the hazard appears to be appreciable to two groups. The first are the seed-eaters feeding directly on seeds pretreated with mercurials. The second are birds at the top of the fresh-water food chain. Although the genetic risks remain to be fully elucidated, there is sufficient evidence to indicate that it exists. It should be possible to reduce greatly the fraction of man's usage that is allowed to escape into the freshwater or land environment and this should be undertaken immediately. The problem of the addition via the combustion of fossil fuel will be more difficult to tackle.

1081. Pearce, J.B. 1972. The effects of solid waste disposal on benthic communities in the New York Bight. In Ruivo, M. (ed.) Marine Pollution and Sea Life. Fishing Trading News (books) Ltd., London: 404-411.

The New York Bight is polluted by about 4 billion liters of raw sewage which it receives daily from the Hudson River and smaller water ways. In addition, over 5 million m^3 of sewer sludge and 6 million m^3 of contaminated dredge spoils are dumped 25 and 22 km respectively from the mouth of the Hudson River. These disposal practices have resulted in a biologically impoverished area of about 30 km^2. Much of this is devoid of any benthic micro or macrofauna and communities surrounding the impoverished areas have very low diversity and biomass. Many of the taxa which are found in these marginal communities are known to be tolerant of low oxygen and high hydrogen sulphide values. Author found that benthic gammarid amphipods were good indicators of environmental deterioration; both amphipod diversity and numbers were inversely correlated with levels of contamination. Larger crustaceans including the crabs, *Cancer irroratus*, and *C. borealis*, and the lobster, *Homarus americanus*, were found to become debilitated and diseased when they migrated into the two waste disposal areas. Author was able to duplicate these pathological developments in controlled environment aquaria. The disease appears to be initiated with fouling of the gills and the branchial cavities. This is followed by the development of severe lesions on the outer exoskeleton and the thin cuticles covering the gills. In most instances the underlying cellular hypodermis is also involved.

Sediments in the biologically impoverished zones are characterized by very high levels of heavy metals, including copper, chromium, and lead, as well as by petrochemicals and organics. Some sediments contained over 30% organic matter. Preliminary information indicates that at least some polychaete worms take up heavy metals. Bacterial decomposition of the organic matter acts to reduce the levels of dissolved oxygen; during the summer months of 1969 and 1970, oxygen was reduced to less than 2 mg/l. It is concluded that the dumping of solid wastes during the past 40 years has seriously affected the ecology of a significant part of the New York Bight.

1082. Pearcy, W.G., and R.R. Claeys. 1971. Zn 65 and DDT residues in albacore tuna off Oregon in 1969. Available from Nat. Tech. Inf. Ser., Springfield, Va., as RLO-2227-T-12-1:1-26.

During their sojourn in Oregon waters in 1969, no significant increase in DDT was found in tuna even though Zn-65 increased drastically as a result of their association with the Columbia River plume. Since rapid uptake of DDT by fish is possible, the hypothesis that the Columbia River is a major source of DDT in the ocean off Oregon is rejected.

1083. Pearcy, W.G., and H.A. Vanderploeg. 1973. Radioecology of benthic fishes off Oregon. In Radioactive Contamination of the Marine Environment. Int. Atom. Ener. Agen., Vienna, Austria: 245-261.

Gamma-emitting radionuclides were found in benthic fishes from depths of 50-2800 m off the Oregon coast from 1964-1971; Zn-65, Co-60, Mn-54, Ce-144, Cs-137, and K-40 were present. Zinc-65, originating mainly from the nuclear reactors on the Columbia River, was the predominant artificially induced radionuclide. Levels of Zn-65 per gram and specific activities of Zn-65 decreased markedly in several species of fishes between 1965 and 1971 because of the shutdown of reactors. This decrease was greater for small than for large Lyopsetta exilis during 1970-1971. Specific activities decreased with increasing depth, both for individual species inhabiting broad depth ranges and for different species inhabiting different depths. Specific activities of Zn-65 were inversely related to body size for L. exilis and Sebastolobus. Other variations of Zn-65 were related to trophic position. Fishes that preyed on low trophic level pelagic animals had higher specific activities than fishes that preyed on benthic invertebrates. Such pelagic feeders may play an important role in accelerating the transport of some radionuclides or elements to the sea floor.

1084. Peden, J.D., J.H. Crothers, C.E. Waterfall, and J. Beasley. 1973. Heavy metals in Somerset marine organisms. Marine Pollution Bull. 4(1):7-10.

Investigations reveal a considerable Cd load in shore crabs (Carcinus maenas) and limpets (Patella vulgata), but it is very unlikely that occasional consumption of small amounts would be harmful.

1085. Pentreath, R.J. 1973. The roles of food and water in the accumulation of radionuclides by marine teleost and elasmobranch fish. In Radioactive Contamination of the Marine Environment. Int. Atom. Ener. Agen., Vienna, Austria: 421-436.

A theoretical estimation of the input of many radionuclides into fish and the relevant roles of food and water, is formulated on the basis of known concentration factors. The importance and methods of estimation of biological half-times in such calculations is also discussed. The accumulation of many fission product nuclides is low due to poor absorption across the gut wall, with the exception of soluble elements such as caesium-137 where both food and water play an equal part. For many neutron activation products, however, the contribution from water alone may be considered to be very small. Experimental evidence is given on the accumulation of certain neutron activation products from water by both teleost and elasmobranch marine fish in relation to their large stable element pools, water fluxes and drinking rates. Calculations on the required dietary input are equated with known feeding rates, and the required retention of such elements is compared with results obtained both from labelled pellets introduced into the gut and from labelled food species. The results imply that, unlike caesium-137, which is increased along the food chain, many neutron activation products (heavy metals) are decreased in concentration at such higher trophic levels. The implication of such work for metal toxicity studies is also discussed.

1086. Pentreath, R.J. 1973. The accumulation from water of ^{65}Zn, ^{54}Mn, ^{58}Co and ^{59}Fe by the mussel, Mytilus edulis. Jour. Mar. Biol. Assn. U.K., 53:127-143.

The accumulation from sea water of Zn-65, Mn-54, Fe-59 and Co-58 by the mussel has been studied in relation to the stable element levels of these isotopes both in the sea water and in individual tissues. For all four radionuclides the greatest accumulation occurred in stomach and digestive gland samples and further localization of Zn-65 and Fe-59 was demonstrated by autoradiography. As the animals were starved during the accumulation period the loss of stable elements by individual tissues was also followed. Again the most notable effect occurred in the digestive gland tissues with the exception of a large loss of iron by the foot. Autoradiography showed that after two weeks accumulation Fe-59 occurs in large clusters in the foot, notably in the byssus gland area. These clusters disappear after a further two week period and may thus be secreted into new byssus threads.

The accumulation of nuclides was examined using a single exponential model and values obtained for flux rates, biological half times and asymptotic values were compared with the stable element concentration factors. An analysis of parameters of exchange of nuclides in individual tissues with the water was further examined which demonstrated that the highest exchange occurs in the order of stomach and digestive gland > gill > foot > mantle > gonad > adductor. This order obtains for all four nuclides studied, despite the fact that in the aquaria used, zinc and cobalt were largely soluble; that manganese was partly in the particulate form with the radionuclide used; and that iron was largely particulate in both stable and active forms. There is an indication that, as well as accumulating nuclides via particulate matter in suspension, the mucus itself is capable of sequestering them, even though they are in the soluble form, and may even preferentially accumulate soluble forms. The actual role of water in accumulation of the nuclides studied appears to be relatively minor compared with that of food accumulation as estimated by difference from the calculated stable element values.

1087. Pentreath, R.J. 1973. The accumulation and retention of ^{65}Zn and ^{54}Mn by the plaice, Pleuronectes platessa L. Jour. Exp. Mar. Biol. Ecol. 12:1-18.

Studies of the uptake and loss of Zn-65 and Mn-54 by flatfish show that direct accumulation from water plays only a minor role relative to food in the metabolism of these metals. Accumulation of both isotopes from water was followed at tissue level and their levels of accumulation were related to stable element concentrations. Biological half-times were also calculated for accumulation and loss to water, for loss of activity following an intraperitoneal injection and, using calculations of feeding rate and assimilation of the isotopes, from food. Some comparative studies were carried out with fed and starved fish. In view of the relatively minor role of direct accumulation from water it was considered that concentrations of these metals would decrease at this level of the marine food chain. The relevance of such observations to toxicity testing is also discussed.

1088. Pentreath, R.J., and D.F. Jefferies. 1971. The uptake of radionuclides by I-group plaice (Pleuronectes platessa) off the Cumberland Coast, Irish Sea. Jour. Mar. Biol. Assn. U.K. 51(4):963-976.

The accumulation of radionuclides by one-year-old plaice in the vicinity of the pipe-line of the UKAEA plant at Windscale, Irish Sea, was studied over a 7-month period. The principal isotope found in flesh was Cs-137, although Ce-144, Ru-106 and Zr-95/Nb-95 were also present in gut contents. The Cs-137 flesh levels were examined in conjunction with fluctuations of this nuclide in sea water, sediment and the gut contents. Of the three major dietary components found throughout the sampling period the calculated intake of Cs-137 from food appeared to fluctuate most closely with the Nephtys fraction of the diet, despite its relatively low Cs-137 content.

1089. Pequegnat, J.E., S.W. Fowler, and L.F. Small. 1969. Estimates of the zinc requirements of marine organisms. Jour. Fish. Res. Bd. Canada 26(1):145-150.

The amount of enzyme-bound zinc is calculated from estimates of total enzyme concentrations and the number of zinc atoms per mole of these enzymes. This estimate is shown to be smaller than measured concentrations in marine organisms, indicating that zinc is accumulated in excess of the organisms' immediate needs. A minimum "potential fertility" for zinc is calculated; the results indicate that zinc is not limiting in the marine environment.

1090. Perkins, E.J., E. Gribbon, and R.B. Murray. 1969. Some aspects of biology of *Carcinus maenas* (L.). II. Survival at low salinity. Trans. Dumfriesshire and Galloway Nat. Hist. Antiq. Soc., 3rd ser. 46:27-28.

Green shore crabs, *Carcinus maenas*, were subjected to a range of salinities from 1.0 to 8.4%, at 8.4°C. Salinities slightly less than 2% were rapidly lethal. Between 2-3% survival was dramatically improved for 1-34 days. Size was important in survival up to 6%, but at 5% salinity, large and small animals survived equally well.

1091. Peterson, C.L., W.L. Klawe, and G.D. Sharp. 1973. Mercury in tunas: A review. U.S. Dept. Comm., Fish. Bull. 71(3):603-613.

Mercury in the aquatic environment comes from both natural processes and industrial activities. The latter probably have not significantly altered the Hg content of the high seas where most tunas are captured. Mercury compounds enter aquatic organisms through the food web or by direct extraction from solution. The relative importance of these pathways in tunas is unknown. Mercury occurs in tuna principally in the form of methylmercury. Generally, tunas appear to have higher Hg levels than those fish species which occupy a lower level in the food chain. Mercury content of tunas varies according to fish size. However, other factors such as area of capture, differential growth rates, varying analytical techniques, and different sampling methods may account for some of the observed variation. The Food & Drug Administration has established an inhouse standard of 0.5 mg of Hg per kg wet wt for fishery products sold in the U.S. Other countries have established limits as high as 1.0 mg/kg.

1092. Pickering, Q.H. 1974. Chronic toxicity of nickel to the fathead minnow. Jour. Water Pollut. Contr. Fed. 46(4):760-765.

Chronic bioassays are the best laboratory method for estimating "safe" concentrations of a toxic substance for fish. The data reported herein indicate that nickel concentrations of 0.38 mg/l and lower do not adversely affect survival, growth, and reproduction of the fathead minnow. However, a nickel concentration of 0.73 mg/l caused a significant reduction on both number of eggs per spawning and hatchability of these eggs. The application factor for a toxicant is calculated by dividing the Maximum Acceptable Toxicant Concentration (MATC) of the chronic test by the LC-50 (96 h) value. This application factor is the decimal fraction used to multiply the LC-50 value to estimate safe concentrations for other species or water quality conditions. The application factor for nickel is between 0.027 and 0.014, based on a MATC value between 0.73 and 0.38 mg Ni/l and the mean of the two continuous-flow 96-hr LC-50 values of 27 mg Ni/l. This application factor is proposed as a first approximation to be used for estimating the MATC value for other species or water quality conditions.

In addition to this study with nickel, chronic toxicity bioassays, using fathead minnows in a similar dilution water, have been conducted with copper, zinc, and cadmium. Of these four heavy metals, copper is the most toxic (96-hr LC-50 and MATC values lowest) and nickel the least toxic. The MATC for copper and zinc was dependent on the effect on reproduction; cadmium was lethal to the developing embryos; and nickel had an effect on both egg production and hatchability. The application factor for these metals ranged from 0.03 to 0.07 for copper and from 0.005 to 0.008 for cadmium. The application factor developed for cadmium is tentative, however, because of the cumulative nature of mortality in the acute tests. At present, the use of application factors developed from chronic toxicity studies is the best tool for estimating the upper limit of the safe concentration of heavy metals in the fish community.

1093. Pickering, Q.H., and M.H. Gast. 1972. Acute and chronic toxicity of cadmium to the fathead minnow (Pimephales promelas). Jour. Fish. Res. Bd. Canada 29(8):1099-1106.

Two continuous-flow bioassays on the chronic toxicity of cadmium to the fathead minnow (Pimephales promelas Rafinesque) indicated that the maximum acceptable toxicant concentration (MATC) for this species is between 57 and 37 μg Cd/l. The experimental concentration of 57 μg Cd/l decreased survival of the developing embryos, the embryos being the most sensitive life stage. At lower concentrations of 37 to 4.5 μg Cd/l, no adverse effect on survival, growth, or reproduction was found. Application factors based on the acute bioassays are discussed in relation to the great variation in toxicity values.

1094. Pickford, G.E., P.K.T. Pang, E. Weinstein, J. Torretti, E. Hendler, and F.H. Epstein. 1970. The response of the hypophysectomized cyprinodont, Fundulus heteroclitus, to replacement therapy with cortisol: Effects on blood serum and sodium-potassium activated adenosine triphosphatase in the gills, kidney, and intestinal mucosa. Gen. Comp. Endocrinol. 14:524-534.

Regulation of the inorganic constituents of the serum is nearly perfect in hypophysectomized Fundulus heteroclitus maintained in salt water, although serum Cl is lower. Chronic treatment with cortisol had no effect on serum Na or serum Ca; serum K and serum Cl decreased, serum inorganic PO_4 and serum Mg increased. Na+K-ATPase activity increased in cortisol-treated fish in three organs that participate in osmoregulation: the gills, the kidneys (males only), and the intestinal mucosa. The increase in the gills can be correlated with a restoration of total Na exchange. The increased activity in the intestine is presumably associated with the increased rate of Na turnover. Increased activity in the kidneys may reflect an increase in the glomerular filtration rate and/or a restoration of renal Na retention. Other effects of cortisol are: a decrease in body weight, an increase in the abundance of circulating erythrocytes, leukocytosis after a single injection or short treatment that is regulated after longer treatment, and an increase in the relative weight of the liver that may be associated with gluconeogenesis. Cortisol had no effect on the relative size of the regressed gonads in either sex.

1095. Pillai, K.C., R.C. Smith, and T.R. Folsom. 1964. Plutonium in the marine environment. Nature 203(4945):568-571.

The authors summarize preliminary findings concerning the plutonium content in sea water, and the concentration factors for this element in certain selected marine organisms. The sea water sample with the lowest activity had more than three times background activity. A sample of plankton obtained in 1950 prior to extensive nuclear testing was measured for plutonium-239 and this also provided background information. The background measured in this way was found to be 0·019 dpm (zero within the accuracy of the measurement).

Marine plants have large concentration factors whereas the negligible concentration by the fish sample indicates that discrimination against plutonium can take place at higher trophic levels. However, these concentration factors should be considered as only a relatively coarse measure of the extent to which plutonium is concentrated in marine organisms from sea water.

An intense bloom 'red tide', which occurred recently in local waters, was used to obtain a sample of phytoplankton large enough for analyses of minute amounts of fallout activity. The organisms caught were largely dinoflagellates, but no determination was made of what sort of organisms escaped or how much of the cell content was lost from the organisms that were caught. The zooplankton samples largely consisted of small copepods and euphausiids and were the only samples preserved in formalin. Concentration factors were between 660 and 1570 for plants, 2590 for plankton, about 260 for mussels and only 3 for bonito (fish).

1096. Pillay, K.K.S., C.C. Thomas, Jr., J.A. Sondel, and C.M. Hyche. 1972. Mercury Pollution of Lake Erie ecosphere. Environmental Research 5(2):172-181.

This distribution of mercury in the ecosphere of Lake Erie was monitored using neutron activation. A variety of samples from the fauna and flora of the lake as well as those from its immediate environment were analyzed for their mercury content. The results of this survey indicate a widespread distribution of mercury in air particulates; coal samples of the region; sediments, plankton/algae and fish samples from the lake; and in the brain tissues of long-time residents of the Lake Erie Basin.

1097. Pilson, M.E.Q. 1974. Arsenate uptake and reduction by *Pocillopora verrucosa*. Limnology and Oceanography 19(2):339-341.

A scleractinian coral removed arsenate from solution and converted some of it to arsenite, which reappeared in the ambient seawater. This suggests that organisms other than bacteria may be responsible for maintaining some of the arsenic in seawater in a reduced form. Reduction of arsenate may be a mechanism to allow the loss from the living cell of arsenate transported in along with phosphate.

1098. Pippy, J.H., and G.M. Hare. 1969. Relationship of river pollution to bacterial infection in salmon (*Salmo salar*) and suckers (*Catostomus commersoni*). Trans. Amer. Fish. Soc. 98(4):685-690.

During the summers of 1967 and 1968, the Pseudomonad bacterium, *Aeromonas liquefaciens*, was involved in disease of Atlantic salmon (*Salmo salar*) and suckers (*Catostomus*) in the Miramichi River, New Brunswick. The symptoms of this disease were ulcers and degenerated caudal, pelvic, and dorsel fins. A surge of copper and zinc pollution in late June 1967, and high river temperatures, 22.5°C, enhanced production of an epizootic. The epizootic recurred during the summer of 1968.

1099. Platts, W.S. 1972. The effects of heavy metals on anadromous runs of salmon and steelhead in the Panther Creek drainage, Idaho. Proc. 52nd Ann. Conf. Western Assn. State Game Fish Comm.: 582-597.

Panther Creek, a tributary of the Salmon River, once supported anadromous runs of salmon and steelhead trout plus resident game fish. Due to mine and mill pollution, the drainage caused loss of these anadromous runs and much of its esthetic value. Heavy metals (copper and iron), in combination with decreased pH and increased sediment, persist in toxic or degrading levels at all times. The mine-mill area with copper content in tributary waters as high as 1200 mg/l increased the copper content in Panther Creek over 30 times natural conditions. The high iron and sulphur input resulted in waters with low pH causing iron to precipitate on the stream channel and also provide energy source for iron bacteria following their domination of some stream sections.

1100. Polikarpov, G.G., Y.P. Zaitsev, V.P. Parchevskii, A.A. Bachurin, and I.A. Sokolova. 1970. Radioecology of Central American seas. *In* Marine Radioecology, Translation of Morskaya Radioekologiya: 256-288. Available from Nat. Tech. Inf. Ser., Springfield, Va., as part of AEC-tr-7299.

Plankton and benthic algae (collected from the Caribbean during April through August 1965) were analyzed by gamma spectroscopy. The principal radionuclides present in the macrophyte *Sargassum natans* were: Ce-144 (93%), Mn-54 (3.6%), Ru-106 (3.1%), and Sr-90 (0.3%); in the benthic brown alga *Padina vickevsiae*, Ce-144 (Ru-106 and Mn-54 were absent). A significant part of the radioactivity in the water and organisms of the upper layers of the Sargasso Sea as in *Sargassum* macrophytes (70% of the Ce-144, 40% of the Ru-106, 7% of the Sr-90, 3% of the Cs-137). In experiments in aquaria, concentration factors were determined for several species of algae (Ce-144, 200-1700; Ru-106, 140-520; Sr-90, 0.5-41; Cs-137, 7-15); for individual organs of macrophytes; for zooplankton; and for other marine organisms. Rates of radionuclide uptake were measured.

1101. Pomelee, C.S. 1953. Toxicity of beryllium. Sewage Ind. Wastes, 25:1424-1428.

Aquaria containing 2 goldfish, 8 minnows and 3 snails in 12 liters of freshwater received daily additions of a complex solution containing 5.3 mg/l Be^{2+}, 56 mg/l SO_4^{2-} and 123 mg/l tartrate. After 10 days, Be^{2+} level measured in water was 28.5 mg/l with no evidence of a toxic effect in test aquaria.

1102. Porcella, D.B., C.E. Rixford, and J.V. Slater. 1967. Factors influencing radiostrontium accumulation in *Daphnia*. Health Physics, 13:391-399.

Authors studied factors affecting strontium accumulation in Daphnid populations (fed algae and bacteria) by analysis for calcium ion and radiochemical determination of radiostrontium (strontium-85). Percent Ca and Sr in *Daphnia* relates to organism's size and Ca concentration in water. Equilibrium concentrations (EC) are expressed as the discrimination factor, K, a ratio of concentration factors (strontium: calcium). Despite dependence of Daphnid size and growth on feeding, EC of two elements are little affected by food chain, evidenced by K=0.64, 0.51, 0.49, 0.51, 0.53 for five EC (range, 3.2-86.9 mg Ca/l). These values approximate K=0.58, determined by others for *Chlorella*, next lower step in food chain. Strontium-85 uptake and release follow first order kinetics. Small *Daphnia* apparently equilibrate before large ones, probably because these ions accumulate primarily in Daphnid carapaces, whereupon uptake depends upon population molting rate. The following model, treating K as constant, approximates observed data: D/W=K (O/C) (1-exp (-KT)), where D=strontium-85 in counts per minute (CPM/milliliter) in water; O=calcium (micrograms/*Daphnia*); C=calcium (micrograms/milliliter) in water; K=reaction rate (dependent upon Daphnid size). Authors suggest that rate of strontium-85 uptake estimates Daphnid population's growth rate.

1103. Potts, W.T.W., and P.P. Rudy. 1972. Aspects of osmotic and ionic regulation in the sturgeon. Jour. Exp. Biol. 56(3): 703-715.

Analyses of blood and urine of the euryhaline sturgeon *Acipenser medirostris* for rates of turnover of sodium and water in fish held in both seawater and freshwater were conducted. The blood concentration is rather lower in freshwater than in seawater and the concentration of magnesium ions declines markedly. The rate of turnover of sodium ions is high in seawater and similar to that of marine teleosts. The rate of turnover of sodium is much lower in freshwater but adaptation to freshwater is slow and the animals are more permeable to sodium than are teleosts. The rate of turnover of tritiated water is more rapid in freshwater than in seawater but in each medium it is similar to that of teleosts of a similar size.

1104. Preston, A. 1973. Heavy metals in British Waters. Nature 242(5393):95-97.

The program of research and development on heavy metals in the marine environment, conducted by the Ministry of Agriculture, Fisheries and Food, has two chief objectives: (1) the establishment and continued monitoring of concentrations in fish and shellfish of commercial importance in Britain to provide a basis for estimates of human intake of heavy metals and (2) to provide data to assist an understanding of the behavior of heavy metals when they are introduced into the marine environment—the factors determining their geographical distribution, or biological fate, including their effect, if any, on marine resources and the kinetics of their metabolism in representative marine organisms. The results of seawater sampling on a pilot scale around the British Isles show that contamination is restricted to a few areas, chiefly, but not exclusively, linked to industrial development, and that even in these areas contamination does not spread very far offshore. Monitoring of commercial fish species shows that, except for sedentary shellfish, variations in inshore seawater metal concentrations are not reflected to any great extent in the edible portions of these species. Concentrations in inshore fish are sometimes higher than those in offshore fish, especially in the case of Cd, Hg, and Pb. This strongly indicates that metal pollution problems are essentially national or regional problems.

1105. Preston, E.M. 1971. The importance of ingestion in chromium-51 accumulation by Crassostrea virginica (Gmelin). Jour. Exp. Mar. Biol. Ecol. 6:47-54.

The relative importance of heterotrophic nutrition and direct absorption in Cr-51 accumulation by oyster, was studied. The accumulation and elimination of Cr-51 in oysters exposed to 50 μc/l $Na_2{}^{51}CrO_4$ dissolved in artificial seawater is compared with that in oysters exposed to the same concentration of Cr-51 associated with the cells of a Chlamydomonas suspension.

At the given exposure concentration, Cr-51 accumulation in oysters occurs more readily by direct absorption than by ingestion. In a natural environment, however, the radioactivity is likely to be greater in the food supply than in the water since most organisms tend to concentrate radionuclides. As a result, the food supply might be the primary source of radioactivity even though accumulation occurs more readily by direct absorption. In these experiments, accumulation by direct absorption alone cannot account for the large concentration factors implied from field assays of Cr-51 in Columbia River organisms.

1106. Price, R.J., and J.S. Lee. 1972. Effect of cations on the interaction between paralytic shellfish poison and butter clam Saxidomus giganteus melanin. Jour. Fish. Res. Bd. Canada 29(11):1659-1661.

The interaction between paralytic shellfish poison (PSP) and butter clam (*Saxidomus giganteus*) melanin was strongly influenced by the presence of cations. The amount of PSP bound by the melanin decreased by 68% in the presence of Al^{+++}, 62 and 57%, respectively, with Ca^{++} and Ba^{++}, and 17 and 15% with Na^{+} and K^{+}. Salt solutions containing 0.01-m Al^{+++}, Mg^{++}, Ca^{++}, Ba^{++}, Na^{+}, or K^{+} induced the desorption of PSP bound to melanin by 54, 34, 28, 19, 11, and 4% respectively. These results confirm an earlier conclusion that the PSP-melanin interaction is reversible and electrostatic in nature.

1107. Pyle, T.E., and T.T. Tieh. 1970. Strontium, vanadium, and zinc in the shells of pteropods. Limnology and Oceanography 15(1):153-154.

X-ray fluorescence analyses of pteropod (mollusca) tests from the Gulf of Mexico provide the first detection of Zn in these shells and the first determination of Sr, V, and Zn concentrations of *Diacria trispinosa* shells. The results suggest further study of the contribution or acceptance of trace elements by pteropods on burial in sediments.

1108. Qasim, S.Z., P.M.A. Bhattathiri, and V.P. Devassy. 1972. The influence of salinity on the rate of photosynthesis and abundance of some tropical phytoplankton. Marine Biology 12:200-206.

Several species of phytoplankton were grown in unialgal, but not bacteria-free, cultures. These clones when exposed to varying salinities, from 5 to $35^{o}/oo$, showed a marked increase in photosynthesis rates at low salinities. The optimum requirement of salinity, however, varied in different species. Observations on the relative abundance of phytoplankton in an estuary, where salinity changes were fairly large, confirmed that waters with low salinities support a greater abundance of phytoplankton in nature. The wide adaptability of phytoplankton to changes in salinity corresponds to conditions brought about by the monsoon system along the southwest coast of India, where large dilutions are associated with the enrichment of water with nutrients.

1109. Rabe, F.W., and C.W. Sappington. 1970. Biological productivity of the Coeur d'Alene River as related to water quality (the acute toxicity of zinc to cutthroat trout-*Salmo clarki*). Idaho Water Res. Research Inst., Completion Rept., Dec. 1970. Available from Nat. Tech. Inf. Ser., Springfield, Va., as PB-197-736:1-16.

Acute toxicity of zinc to trout fingerlings was determined using two bioassay systems. In a static bioassay, 24, 48 and 96 hr LC-50 values of 0.62, 0.27 and 0.09 mg/l of zinc respectively, were obtained. Results of a recirculating, flowing-water bioassay showed an LC-50 (24 h) value of 0.42 mg/l zinc; 48 and 96 hr values were not determined.

1110. Rabe, F.W., R.C. Wissmar, and R.F. Minter. 1973. Plankton populations and some effects of mine drainage on primary productivity of the Coeur d'Alene River; Delta; and Lake. Water Res. Research Inst., Univ. of Idaho, Moscow, Idaho, Tech. Comp. Rept. OWRR Proj. No. A-030-IDA: 1-20.

Variations in primary production and physiochemical measurements in the Coeur d'Alene River and Lake contaminated by mine and industrial wastes were examined from May, 1969, to November, 1970. Primary production ranged from 17.6 to 1337.9 mg C/m^2/day in the Coeur d'Alene River and 69.3 to 1714.5 mg C/m^2/day in the Coeur d'Alene Lake. Concentrations of zinc (0.1 to 11.2 mg Zn/l) and copper (0.0 to 0.6 mg Cu/l) in the Coeur d'Alene River indicated that heavy metals could be toxic to algae. Diatoms dominated phytoplankton in the Coeur d'Alene River, Lake, and St. Joe River.

Nannoplankton from Coeur d'Alene Lake were exposed to known concentrations of Cu^{2+}, Cd^{2+}, Zn^{2+} and dilutions of Coeur d'Alene River water under controlled light and temperature. Inhibitory effects of separate and interacting metals on carbon-14 uptake by algae were assessed. Copper, cadmium, and zinc were acutely and synergistically toxic to carbon uptake by phytoplankton. Concentrations ranged from 0.05 to 0.75 mg Cu/l, 0.1 to 0.3 mg Cd/l, and 0.1 to 1.5 mg Zn/l. Copper caused an overriding effect on two- and three-way interactions of Cu^{2+}, Cd^{2+}, and Zn^{2+}. Dilutions of Coeur d'Alene River water decreased Cu and Zn toxicity. Variable algal community structure, major cations, softwater (<60 mg/l as $CaCO_3$), and other factors affect metal toxicity.

1111. Rachor, E. 1972. On the influence of industrial waste containing H_2SO_4 and $FeSO_4$ on the bottom fauna off Helgoland (German Bight). In Ruivo, M. (ed.). Marine Pollution and Sea Life. Fishing Trading News (books) Ltd., London: 390-392.

Since May 1969 a daily quantity of about 1600 tons of waste acid (containing 10% H_2SO_4 and 14% $FeSO_4$ + minerals) have been discharged by special tankers into an area 20 km northwest of Helgoland. The area is part of a medium sand region occupied by a community of low biomass. Since April 1969 regular monthly investigations have been carried out by taking samples in the polluted area as well as in comparison areas. Results after one year of research show little alteration in the ecosystem.

1112. Rahimian, H. 1972. The effect of calcium on growth and morphogenesis of *Chlorella*, *Golenkinia*, and *Scenedesmus*. Ph.D. Thesis, Wash. State Univ. Available from University Microfilms, 300 No. Zeeb Rd., Ann Arbor, Mich., 48106, Order No. 73-73.

Morphogenetic effects of calcium on *Chlorella pyrenoidosa*, *Scenedesmus obliquus*, and *Golenkinia minutissima* were studied, as were effects of strontium, barium, and ethyleneglycol bisaminoethylether tetraacetic acid (EGTA) on *Scenedesmus*. Inoculated cells were starved in a calcium-free medium for one week before the time of inoculation. Organisms were grown under controlled conditions at the temperature of about 20°C and illuminated with an intensity of 350 ft-c from cool-white fluorescent lamps regulated to provide 16 hours of light and 8 hours of darkness. Cultures were aerated with a mixture of 3% CO_2 in air. Growth was measured in terms of increase in the cell population and increase in amount of fresh and dry matter. The results were as follows: (1) Calcium was necessary for maximum production of cell number in each species. (2) With Ca, cultures yielded a greater biomass on a wet and dry wt basis. (3) Starch content of cells was greater with Ca. (4) The K/Na ratio was greater in the presence of Ca. (5) Number of cells produced was significantly decreased when Sr or Ba was substituted. (6) Calcium played a role in cell morphology. (7) Calcium was shown to be necessary for colony formation in *Scenedesmus*. (8) Cell size was found to be inversely proportional to the number of cell production. (9) Seta formation in *Golenkinia* was shown to require Ca. (10) In the presence of higher than 0.6 mM of EDTA, a specific chelating agent for Ca, the algal cells died. (11) It is hypothesized that Ca is required for activating enzymes involved in wall formation and cell division as well as for maintaining membrane integrity. This has already been established for uridine diphosphoglucose pyrophosphorylase and uridine diphosphoglucose fructose transglycosylase which function in wall formation.

1113. Rao, G.M.M. 1971. Influence of activity and salinity on the weight-dependent oxygen consumption of the rainbow trout *Salmo gairdneri*. Marine Biology 8:205-212.

Standard and active rates of oxygen consumption of rainbow trout (*Salmo gairdneri*) acclimated and tested at 5° and 15°C in various salinities (freshwater to 30^{o}/ooS) were determined. The fish used in experiments ranged in weight from 23 to 196 g. Lowest rates of oxygen consumption were obtained in 7.5^{o}/oo at both temperatures and at all levels of activity; maximum rates were obtained in 30^{o}/oo with the exception of smaller fish at 15°C. Reduction in osmotic load/cost of osmoregulation is suggested as the probable cause for the lowest rate of oxygen consumption in 7.5^{o}/oo, a salinity isosmotic with fish plasma. Increase in temperature results in increase of metabolic rate. However, this has no effect on the slope of the weight-metabolism regression line. In 30^{o}/oo at 15°C, the response at higher levels of activity seems to be size-dependent. The slope of the regression line (weight versus oxygen consumption) increases with increasing activity at 15°C; this is more pronounced in 30^{o}/oo. However, at 5°C no significant statistical difference was observed between the slopes. The scope for activity was calculated. It was found to be lowest in 7.5^{o}/oo, and the scopes in freshwater and 15^{o}/oo were not different. The scope in 30^{o}/oo was high at 5°C, a reduced scope was found for smaller fish; this is a reflection of the earlier observation that small fish were unable to survive in a high salinity/high temperature combination.

1114. Rao, T.R. 1974. Influence of salinity of the eggs and larvae of the California killifish, Fundulus parvipinnis. Marine Biology 24:155-162.

Effects of salinity on embryonic development and survival were determined for eggs and larvae of F. parvipinnis. Incubation salinities over the range of 5 to 14^{o}/oo produced the shortest incubation period, maximum yolk-conversion efficiency, largest larval size at hatching, and maximum viable hatch. Various morphometric measurements of the newly-hatched larvae were influenced significantly by incubation salinity. Fertilization salinity also affected certain development criteria; in general, lower fertilization salinities resulted in shorter incubation periods and larger larvae at hatching. A salinity range of 5 to 14^{o}/oo is suggested as a physiological optimum, and the known freshwater affinity of the species suggests that an eventual freshwater colonization by the California killifish is possible.

1115. Ratkowsky, D.A., S.J. Thrower, I.J. Eustace, and J. Olley. 1974. A numerical study of the concentration of some heavy metals in Tasmanian oysters. Jour. Fish. Res. Bd. Canada 31:1165-1171.

Zn, Cd, and Cu concentration was determined in 473 oysters grown at a variety of places around the Tasmanian coastline. A close association was obtained between proximity to heavily urbanized areas and concentration of metals found, oysters growing nearest urban areas having the highest concentrations of one or more of the metals. It appears that areas for commercial oyster growing should be sought in regions far from centers of urbanization and industrialization. Examination of samples of native oysters could be useful in providing an index or measure of environmental pollution.

1116. Ravera, O. 1971. Sr-85 and Cs-134 uptake by freshwater seston. Rev. Int. Oceanograph. Méd. 21:109-124.

Strontium-85 and cesium-134 concentrations in different granulometric fractions of seston collected in Lake Monate, Italy, are determined. These data indicate that cladocerans concentrate Sr-85 to the highest degree and with phytoplankton it was Cs-134. It is assumed that absorption radionuclides predominate over adsorption. Schematization of the vertical distribution of radiostrontium and radiocesium present in different granulometric fractions is attempted from the data on the distribution of the biomass of seston at different depths and the concentration of two radioisotopes computed in different granulometric fractions of seston.

1117. Raymont, J.E.G. 1972. Some aspects of pollution in Southampton water. Proc. Royal Soc. London, Ser. B 180(1061):451-468.

The following topics, as related to pollution, were discussed: (1) trace metals, (2) nutrients, (3) dissolved and particulate organic matter, and (4) thermal effects. From previous works it has been shown that the concentration of particulate iron depended significantly upon the total particulate matter of the area. Zn, Cu, and Ni variations appear to be correlated with local industrial pollution. Fe, Zn, Cu, and Hg were magnified by the bivalves *Mercenaria mercenaria*, *Cardium edule* and *Mytilus edulis*. A relationship between turbulence and metal concentration appears extant, since higher concentrations of metals were present in mussels from turbulent areas than from clear waters. Such a factor will be important on studies of pollution of estuaries, since it suggests that trace elements in sediments may be stirred into suspension. Nutrient levels in this Southampton area have risen such that further increases might have deleterious effects. Thermal changes appear to have no harmful effects other than propagating growth of certain species in lieu of others (*Elminius modestus*). The degree of variability between particulate and dissolved organics was associated with turbulence and effluent concentrations, and varied according to the degree of industrialization and urbanization along the water-way.

1118. Reay, P.F. 1972. The accumulation of arsenic from arsenic-rich natural waters by aquatic plants. Jour. Appl. Ecol. 9(2): 557-565.

Several aquatic plants were found to accumulate As from the Waikato River (New Zealand) to levels well above those associated with toxicity. The species examined differed in the concentrations to which the accumulated As and the average values ranged from 30-650 mg/kg of the dry weight. Accumulation was influenced by the amount of As in the water but not by the amount in the river and lake bottoms. The withdrawal of As from the river water by aquatic plants does not seem to markedly affect the discharge of As into the sea.

1119. Reeves, W.C., and J.F. Germann. 1972. Effects of increased water hardness, source of fry and age at stocking on survival of striped bass fry in earthen ponds. Proc. 25th Ann. Conf. Southeastern Assoc. Game Fish Comm., Oct. 17-20, 1971:542-548.

Investigations were conducted to determine the effect of water hardness, source of fry and immediate versus delayed stocking on the survival of striped bass fry. Twelve 0.10-acre earthen ponds were used, of which 6 were treated with calcium sulfate to raise the hardness to 150 mg/l. The hardness of the remaining ponds was approximately 20 mg/l. Fry from two sources (Cooper River, South Carolina, and Savannah River, Georgia) were stocked immediately after receiving them from the hatchery or after they began feeding. Stocking rates varied from 60,000/A to 210,000/A. There was no difference in survival between sources of fry. Delayed stocking increased the survival rate of striped bass; however, many fry from each source died in holding prior to stocking. Increasing the water hardness did not increase the survival of striped bass. On the contrary, survival of striped bass in soft water ponds was higher than the survival in hard water ponds.

1120. Rehwoldt, R., G. Bida, and B. Nerrie. 1971. Acute toxicity of copper, nickel and zinc ions to some Hudson River fish species. Bull. Environ. Contamin. Toxicol. 6(5):445-448.

The effect of some common industrial inputs upon the life expectancy of Hudson River fishes was investigated by means of bioassays. Copper was the most toxic to all species. The range of concentration for 24 hours was 1.5 mg/l for the banded killifish to 11.6 mg/l for the white perch. Nickel was the least toxic metal for all species except the American eel. Zinc is more toxic than nickel and for the striped bass the toxicity is almost the same as that for nickel.

1121. Rehwoldt, R., L. Lasko, and C. Shaw. 1973. The acute toxicity of some heavy metal ions toward benthic organisms. Bull. Environ. Contamin. Toxicol. 50(5):291-294.

A study was conducted to determine the toxicity of some heavy metal ions toward benthic fauna in a freshwater region of the Hudson River. Metal ions evaluated were copper, zinc, nickel, cadmium, mercury, and chromium. Water quality during the experiment was maintained at 17°C, 50 mg/l hardness, 7.6 pH, and 6.2 mg/l dissolved oxygen. Mercury was the most toxic ion toward the test organisms (bristle worms, scud, caddisflies, damselflies, midges, and snails) and was more toxic toward these organisms than toward fish studied earlier in the same area. However, with the exception of the scud and midge, benthic organisms tend to be more able to withstand heavy metal inputs than fish.

1122. Rehwoldt, R., L.W. Menapace, B. Nerrie, and D. Alessandrello. 1972. The effect of increased temperature upon the acute toxicity of some heavy metal ions. Bull. Environ. Contamin. Toxicol. 8(2):91-96.

Several species of fish, including banded killifish, striped bass, pumpkinseed, white perch, American eel, and carp, were exposed at 28°C to Cu, Zn, Ni, Cd, Hg, and Cr ions to determine the mean toxicity limit for 50% survival. The 28°C temperature was chosen because it represents the ambient temperature of the thermal plume of the Danskammer Point power station in the town of Newburgh, New York. Water temperature in test tanks was maintained by standard aquarium heaters. Toxicity data are tabulated for 24, 48, and 96 hours in terms of metal ion concentration and also relative to existing ambient background concentrations in the river during the course of the investigation. The latter data show the magnitude of change that would have to occur in the receiving water to produce a fish kill. Comparison of toxicity values at 28°C with data from tests at 15°C shows that toxicities at the two temperatures are not significantly different except with mercurous ions. For carp-like fish it was concluded that mercurous ion toxicity was about three-fold for a 10°C increase in temperature.

1123. Renfro, W.C. 1970. Radioecology of Zn-65 in Alder Slough, an arm of the Columbia River Estuary. Contract No. AEC AT (45-1)-1750:1-43. Available from Nat. Tech. Inf. Ser., Springfield, Va., as RLO-1750-46.

The transfer of Zn-65 through a small estuarine ecosystem was investigated by determining seasonal changes in concentrations of Zn-65; total Zn; Zn-65 activities in water, sediments, plants, and animals; and rate of Zn-65 turnover by various organisms. The area for study was Alder Slough, a small body of water about 0.6 km upriver from the mouth of the Columbia River. Samples of water, sediments, emergent plants, algae, fish, shrimp, and amphipods were collected for analysis. Zn-65 in water samples was co-precipitated for analysis.

Emergent plants and algae were dried, and fish, shrimp, and amphipods were preserved in formalin prior to radioanalysis with an NaI well crystal coupled through a photomultiplier to a multichannel analyzer. Total zinc in plants and animals was determined by atomic absorption. The concentrations and fluctuations of Zn-65 are discussed.

1124. Renfro, W.C. 1973. Transfer of ^{65}Zn from sediments by marine polychaete worms. Marine Biology 21:305-316.

Silty marine sediments spiked with Zn-65 lose only small fractions of their radioactivity when exposed to slowly flowing seawater for several weeks. However, polychaete worms (*Nereis diversicolor*), burrowing through the sediment, cause Zn-65 losses to 3 to 7 times higher than in sediment without worms. Long-term experiments on the uptake and loss of Zn-65 by the polychaete *Hermione hystrix* indicate that 60 or more days exposure are required for this worm to approach steady state with Zn-65 in the sediment. Biological half-life estimates for Zn-65 accumulated from sediment by *H. hystrix* are extremely variable (52 to 197 days), depending on the loss-time interval chosen for the calculation. Following 5 days exposure to 16 cm^3 of radioactive sediment, *N. diversicolor* individuals contained an average of 0.2% of the total Zn-65 in the sediment. When these worms were transferred to non-radioactive sediment, estimates of biological half-life for Zn-65 averaged 14 to 17 days during the loss period Day 3 to Day 15. Based on these experimental results, it is estimated that a population of *N. diversicolor* could cause an annual loss of 3% or more of the Zn-65 in the upper 2 cm of the sediment of a hypothetical radioactive estuary.

1125. Renzoni, A., E. Bacci, and L. Falciai. 1973. Mercury concentration in the water, sediments and fauna of an area of the Tyrrhenian Coast. *In* 6th Int. Symp. Medicale Ocean., Portoroz, Yugoslavia, Sept. 26-30, 1973:17-45.

Preliminary results are reported of a first year of study of mercury concentrations in water, sediments and in representative fauna of a wide strip along the Tuscan coast where the effluent from a large chloralkali factory discharges its wastes. Among the most interesting: the presence of high concentrations of mercury in the water of a larger area than had been thought, reaching values as high as 204 ng/l in the most polluted station; evidence of a relationship between the mercury concentration and the size of the sediment granules; great differences in mercury content between animals of different phyla, and, within the same phylum, between groups and species; great variations in mercury concentration in different tissues of the same specimen, with consistently higher values in the visceral organs than in the muscles in all specimens of all studied species; an evident mercury accumulation in the white muscle of the small-scaled sea-scorpion; no evident mercury accumulation in the foot muscle of the limpet.

1126. Reynolds, W.W., and D.A. Thomson. 1974. Temperature and salinity tolerances of young Gulf of California grunion, *Leuresthes sardina* (Atheriniformes:Atherinidae). Jour. *Marine Res. 32(1)*:37-45.

Newly hatched prolarvae were more eurythermal than older fish. Salinity tolerance also decreased with age, from 4-67.5^{o}/oo at hatching to 5-57.5^{o}/oo at 30 days post-hatching.

1127. Reynolds, W.W., and D.A. Thomson. 1974. Ontogenetic change in the response of the Gulf of California grunion, *Leuresthes sardina* (Jenkins & Evermann), to a salinity gradient. *Jour. Exper.* Mar. Biol. Ecol. 14:211-216.

Newly hatched prolarvae selected salinities in the range 15-24^{o}/oo, while late postlarvae and juveniles preferred salinities in the range 45-54^{o}/oo. Early postlarvae exhibited a bimodal preference, indicating that the behavioral change was in progress at that age.

1128. Rice, T.R. 1963. The role of phytoplankton in the cycling of radionuclides in the marine environment. *In* Schultz, V., and H.W. Klement, Jr. (eds.). Radioecology. Reinhold Publ. Corp., New York: 179-185.

The importance of phytoplankton in passing radionuclides up the food web depends upon the number and amount of radionuclides accumulated, the length of time these radionuclides are retained by the phytoplankton, the size of the phytoplankton cells and the number of cells present in the water, and the efficiency of digestion of the cells by filter-feeding animals.

It has been shown both in the laboratory and under field conditions that phytoplankton accumulate a large number of elements from sea water and are, therefore, very important in the removal of radionuclides. The availability of a radionuclide is dependent to a large extent upon its physical state in sea water. Radionuclides in the colloidal and particulate states are accumulated as well as radionuclides in the ionic state. Actually cerium-144 in the particulate state was accumulated more rapidly than cerium-144 in the ionic state. The accumulation of a radionuclide by phytoplankton depends both upon the total amount of the element present in sea water and the quantities of other metabolically similar elements. All species of phytoplankton will not be equally important in the cycling of all radionuclides in the oceans, based on their capacity to concentrate radionuclides. For phytoplankton to be of importance in the passage of radionuclides up the food web it is not only necessary that the cells accumulate the radioactivity, but also that it be retained for considerable periods of time. Division of radioactive phytoplankton in nonactive water results in a 50% reduction of activity per cell with each division. This has been referred to as "biological dilution." The amount of phosphorus-32 exchanged by *Nitzschia* cells varies with the concentration of phosphorus in the medium in which the cells were grown, the physiological condition of the cells, and the length of time the cells were grown in medium containing phosphorus-32. Even though phytoplankton remove large amounts of radionuclides from sea water, the amount that can be passed up the food web will vary with cell size and total numbers of cells in the water since these are among the more important factors affecting the efficiency of the filtering mechanism of filter-feeding animals. Different species of phytoplankton that accumulate a radionuclide to the same level and are removed from the water with the same efficiency by a filter-feeding animal may not result in these animals becoming equally radioactive. This is due to all species of phytoplankton not being digested with the same efficiency. Radioactive cobalt was concentrated to higher levels in *Artemia* when these animals fed upon radioactive *Carteria* cells than when the activity came from the water. It was concluded that phytoplankton are important in the cycling of radionuclides in the oceans.

1129. Rice, T.R. 1963. Review of zinc in ecology. In Schultz, V., and A.W. Klement, Jr. (eds.). Radioecology. Reinhold Publ. Corp., New York: 619-631.

Zinc has been shown to be an almost universal constituent of living matter and is considered essential for the growth and normal development of most microorganisms, plants, and animals. It is now necessary that the role of zinc in the terrestrial, freshwater, and marine environments be delineated since zinc-65 has been shown to be present in all three. Zinc-65 occurs in these environments as an induced radionuclide, produced at the time of nuclear detonations or in water used as a coolant for nuclear reactors. It has a half-life of 245 days and has been used widely for biological studies. Difficulties encountered in the analytical determination of zinc at levels existing in plants and animals and equal difficulties of freeing water and reagents from contamination with zinc have been deterrents to zinc research.

Some soils naturally contain insufficient total or available zinc to meet the requirements of plant growth. On these soils the use of zinc-containing sprays and fertilizers has become standard agricultural practice. Direct foliate absorption through the leaves of sprinkler-irrigated crops has been shown to be an important pathway in the uptake of zinc-65. Zinc-deficiency symptoms in plants have resulted from excessive liming of the soil and on soils containing a high phosphate content. Plants apparently vary greatly in their zinc requirements and also in their ability to obtain zinc from a given soil. Zinc-65 taken up by bean plants was found to be present in greatest quantities in the roots. High concentrations of phosphate prevent zinc from being uniformly distributed throughout the plant. It is not commonly retranslocated from older leaves to younger leaves as the plant grows. Zinc-65 has been found in all farm produce sampled from an irrigation project about 30 miles downstream from the Hanford reactors. The distribution of zinc-65 in a beef animal from this project was determined. Hair, bone, and liver were found to concentrate it to a greater extent than the other tissues.

Zinc-65 can exist in the following three phases in the aquatic environment: water, sediment, and biota. At any given time, factors are in operation in this environment tending to dilute and disperse radioactive materials while simultaneously other conditions are concentrating the radionuclide. The quantity of zinc that occurs in fresh water varies considerably from one location to another. Zinc-65 has a marked tendency to be fixed in or on planktonic organisms and suspended silt. Zinc-65 is readily transferred through the food web and occurs in relatively large concentrations in most all Columbia River organisms sampled. Many radionuclides in fish in the Columbia River decreased greatly during the winter but concentrations of zinc-65 remained relatively constant throughout the year. Zinc-65 occurred in all tissues of fish examined, with concentrations in the eye three or more times greater than in any other tissue.

In the last few years considerable emphasis has been placed on the advantages of the sea as a disposal site for radioactive wastes. Zinc-65 is among those radionuclides which could be more dangerous to man when occurring in the oceans. Analyses of marine plants and animals have shown that the concentration of zinc in them exceeds the concentration in sea water by 1,000 times or more. The amounts of zinc occurring in natural sea water are far in excess of the needs of a culture of phytoplankton. Above the first trophic level the rate of accumulation of zinc-65 may be influenced by whether the uptake of the nuclide is occurring from only the water or the food of the animal. Artemia obtaining zinc-65 from food contained more zinc-65 throughout an entire experiment than other Artemia obtaining zinc-65 from water. The physiological condition of the animal and the temperature of the water are among the factors influencing the rate of loss of zinc-65 from marine animals. Loss of zinc-65 from marine animals placed in sea water containing no zinc-65 occurs at a slower rate than the rate of accumulation. This phenomenon is very important in instances of acute pollution since animals will retain zinc-65 for a longer period than the zinc-65 will be maintained at any appreciable level in the water. This will result in observed concentration factors being higher than they would have been if the availability of the zinc-65 had been maintained in the water.

1130. Riley, J.P., and I. Roth. 1971. The distribution of trace elements in some species of phytoplankton growth in culture. Jour. Mar. Biol. Assn. U.K. 51:63-72.

Fifteen species of phytoplankton, representative of several marine classes, have been grown in the same artificial medium under similar conditions. The organisms were harvested after 20-30 days, ashed in atomic oxygen, and analyzed spectrographically for Mn, Zn, Cu, Ag, Pb, Sn, Ni, Be, V, Al, Ti, Bi, Ba, Cr, Sr, Co, Fe, Ga, and In. It was found that the organisms could accumulate most of the elements sought, and that there were no differences in their distribution patterns which could be correlated with the classification of the organisms. In another series of experiments a study was made of the uptake of trace elements by four species of phytoplankton growing in media having various levels of chelated trace metals.

1131. Riley, J.P., and D.A. Segar. 1970. The distribution of the major and some minor elements in marine animals. I. Echinoderms and coelenterates. Jour. Mar. Biol. Assn. U.K. 50:721-730.

A scheme employing atomic absorption spectrophotometry, flame photometry and colorimetry has been developed for the determination of Ag, Al, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, Pb, Sn, Sr, and Zn in marine animals. The distribution of these elements in 7 echinoderms and 2 coelenterates has been studied. Figures are presented for their concentrations in the dissected parts of Echinus esculentus, Spatangus purpureus and Asterias rubens. Trace metals are most strongly concentrated in the digestive parts of the organisms, less so in the gonads, and least in the skeletal tissues. Of these metals zinc attains the highest concentration, in some instances copper, nickel, and cadmium are also quite strongly concentrated.

1132. Rissanen, K., J. Erkama, and J.K. Miettinen. 1972. Experiments on microbiological methylation of mercury (2+) ion by the mud and sludge under aerobic and anerobic conditions. In Ruivo, M. (ed.). Marine Pollution and Sea Life. Fishing Trading News (books) Ltd., London: 289-292.

The tragic mass poisonings by methylmercury in fish of the local fish-consuming populations in Minamata and Niigata, Japan, between 1953-65 and the alarmingly high mercury contents of fish in many waters in Scandinavia, have drawn wide attention to mercury as a pollutant of fresh and coastal waters. A major problem in the mercury pollution of fish is the transformation of inorganic mercury to methylmercury: in Scandinavia nearly 100% of the mercury in fish is in the form of methylmercury, even in waters where all pollution has been in the form of inorganic or phenylmercury

In this study investigations were conducted on formation of methylmercury from inorganic mercury ion by four preparations (garden soil, bottom mud of a eutrophic lake, activated sludge, and incubating sludge, both from a sewage treatment plant) in anaerobic conditions using the tracer Hg-203. No methylmercury was formed during 34 days in these experiments. Methylation of 0.1% of the mercury added could have been detected.

1133. Rivers, J.B., J.E. Pearson, and C.D. Schultz. 1972. Total and organic mercury in marine fish. Bull. Environ. Contamin. Toxicol. 8(5):257-266.

Total and organic mercury levels are given for the muscle tissue of certain pelagic and inshore fish of Hawaii which are used for human consumption.

1134. Robertson, D.E. 1971. Influence of the physiochemical forms of radionuclides and stable trace elements in sea water in relation to uptake by the marine biosphere. Available from Nat. Tech. Inf. Ser., Springfield, Va., as BNWL-SA-4048:1-60.

This review presents examples of dissimilar biological uptake between important artificial radionuclides (Fe-55, Zn-65, and Ru-106) and their stable isotopes in the marine environment. Although definitive work is needed, there is evidence that Zn, Fe, and Cu are present as soluble metal chelates. Ru, Fe, and Mn hydrolyze to form polymeric species. But, Pu is in particulate form. The relatively high uptake of Pu by seaweeds and certain crustaceans appears to be a surface absorption process. The maximum permissible concentration of Pu in seawater is about 6 x 0.01 microCi/ml, based upon a single intake of 200 gms of fish per individual.

1135. Romeril, M.G. 1971. The uptake and distribution of ^{65}Zn in oysters. Marine Biology 9:347-354.

Over a period of 6 weeks in aquaria, Portugese oysters Crassostrea angulata, accumulate Zn-65 to a greater extent than do native Ostrea edulis, although intake rates for any particular organ in either species are quite similar. The general distribution pattern of radioactivity in the tissues is similar to that observed for stable zinc and Zn-65 in other oyster species, concentration occurring to the greatest extent in gills and mantle, and least in muscle. The observed equilibrium concentrations and biological half-lives are considerably less than those measured in the natural environment, and the significance of this and its bearing on the mechanism of uptake is discussed. Cobalt and iron depress the rate of Zn-65 uptake by both oyster soft tissues and the shell. The limiting effect in soft tissues is probably due to competition for sites at the actual point of uptake. The distribution of Zn-65 in tissue subcellular fractions separated by centrifugation shows the greatest concentration of the radioisotope in the insoluble tissue components of gills, mantle and heart. Appreciable amounts of Zn-65 are associated with tissue proteins.

1136. Romeril, M.G. 1974. Trace metals in sediments and bivalve mollusca in Southampton Water and the Solent. Revue Int. Océanogr. Médicale 33:31-47.

Two species of bivalve mollusca, the hard shell clam and the common cockle, collected every other month for one year at a number of sites in Southampton Water and the Solent, England, have been analyzed to determine the concentration of zinc, copper and iron in their soft tissues. Sediment samples from the estuary have also been analyzed. Significant variations in tissue metal content occurred with locality, season and age of organism. These variations are discussed in relation to conditions in the estuary and, in particular, to metal concentrations in the sediments.

1137. Roosenburg, W.H. 1969. Greening and copper accumulation in the American oyster, Crassostrea virginica in the vicinity of a steam electric generating station. Chesapeake Science 10(3): 241-252.

Oyster meats near the outfall of a steam electric generating station in the Patuxent River, Maryland, started to display green color shortly after initiation of plant operation. In time, the affliction increased in intensity and spread to oyster stations farther removed from the outfall. The greening of Patuxent oysters was probably caused by copper uptake, since green color and copper concentration (mg of copper per g dried meat weight) were closely correlated. Copper content of oysters decreased with distance from the outfall. There was an inverse relationship between oyster condition and copper concentration.

This was most evident at stations near the outfall where oysters had high copper content. Amounts of copper per oyster, based on mg of copper per liter shell cavity volume, did not display great seasonal fluctuation. Oysters at special stations, established to investigate a possible copper source upstream from the plant, showed a reduction in mg of copper per g dried meat, while oysters at stations inside and near the outfall increased sharply in mg of copper per g dried meat. Indications in the Patuxent point to a relationship between oyster copper uptake and power plant operation.

1138. Rowe, D.W., and E.J. Massaro. 1974. Cadmium uptake and time dependent alterations in tissue levels in the white catfish *Ictalurus catus* (Pisces: Ictaluridae). Bull. Environ. Contamin. Toxicol. 11(3):244-249.

Fish receiving a single intragastric dose of 0.2 mg/l of Cd as cadmium chloride were found to regurgitate from 39% to 56% of the dose solution within one hour. After one hour, 75% of the Cd body load was contained within the gastrointestinal (GI) tract, with 62, 10 and 3% in the stomach, esophagus, and first 1/3 of the intestine, respectively. Gill filaments contained 23% of the total body activity. Within 24 h, there was a marked change in distribution; relative concentrations in stomach, esophagus, gill filaments and skin decreased to 31%, 2%, 1.0% and background, respectively, while the first and second portions of the intestine increased to 47% and 16%, at the same time the kidney concentration increased to 2%. The intestinal portions attained maximum levels at widely divergent times. Thus, the first, second and third portions of the intestine maximized at 78%, 16% and 27%, respectively, after 8, 1 and 4 days, respectively. Outside the GI tract, liver and kidney contained the highest percentages of the body load: 5% and 34%, respectively, at 21 days (termination of experiment). Examination of liver and kidney data suggests that these organs may not have reached their relative maximum concentrations at this time. Other tissues and organs contained less than a maximum of 0.8% of the body load. There appears to be a trend toward accumulation in blood, spleen, swim bladder and ovaries. On the other hand, there appears to be no trend toward accumulation in the muscle, bile, bone, brain and lens. The presence of Cd in the gill filaments is probably an artifact of regurgitation. This hypothesis is supported by the observation that levels in gill filaments and the esophagus decrease from 23% and 10% of the body load, respectively, to 1% and 2%, respectively, in 24 hours. Furthermore, within this time period the blood was not observed to contain a significant percentage (0.04%) of the body load.

1139. Rozhanskaya, L.I. 1970. Mn, Cu and Zn in water and organisms of the sea of Azov. Available from Nat. Tech. Inf. Ser., Springfield, Va., as Part of AEC-tr-7299; Translation of Morskaya Radioekologiya (Marine Radioecology): 222-225.

Mn in near-bottom water varied with season and location and was inversely related to the oxygen content. The average Cu/Zn ratio was 0.39. Phytoplankton, zooplankton, and benthic organisms had generally higher concentration factors for trace elements (Mn, 200-10,000; Cu, 250-3,000; Zn, 500-7,000) than fish (Mn, 30-400; Cu, 150-700; Zn, 700-1,800). Migration of Sr-90 in coastal zones is affected by absorption into the macrophyte biomass.

1140. Ruf, H., and H. Rohde. 1973. Determination of mercury contents in diverse samples of fish and other biological materials by neutron activation analysis. Zeit. Analyt. Chem. 263(2):116-120.

Mercury content in diverse samples of fish and other biological materials were determined by neutron activation measuring the activity of Hg-197. Abnormally high content of mercury was found in some samples of Japanese canned tuna and in whitefish from the Rhine River.

1141. Sabodash, V.M. 1970. Dynamics of zinc concentration in the early developmental stages of carp. Hydrobiol. Jour. 6(3): 59-65.

Zinc content of carp roe from adults of different ages varies, being highest in roe from 3-year-old carp (47 mg/100 g of dry substance on the average), and lowest (29 mg) in roe of 6- to 7-year-old fish; intermediate values were established for fish of intermediate age. Zinc in zygotes from young adults decreased sharply between fertilization and gastrulation to 20 to 23 mg/100 g of dry substance, after which it tended to accumulate slightly in larvae. This stage-by-stage variability in zinc content of zygotes and larvae from middle-aged fish was similar to that of the youngest fish, but the tendency for zinc to accumulate in larvae was manifested somewhat sooner and to a greater degree. Unlike offspring of young and middle-aged fish, zinc content of zygotes from oldest fish did not drop, but rose from 16 to 21 mg/100 g of dry substance, remained constant until hatching, then increased, plateaued, and decreased slightly. Thus, the original amount of zinc inherited by mature oocytes from parents influenced dynamics of elimination and accumulation of this element in carp in embryonic and early postembryonic periods of development. This feature of stage-by-stage variability in zinc content of carp embryos and larvae was confirmed by laboratory experiments using $ZnSO_4$ (5 mg/l) on carp roe and larvae.

1142. Sabodash, V.M. 1971. Localization of zinc in carp spawn, embryos, and larvae. Hydrobiol. Jour. 7(1):36-41.

A histochemical technique was used to detect zinc in ovulated carp spawn and larvae during different stages of development. Zinc concentrated in ovulated spawn and in yolk granules of hatched larvae with a yolk sac. After resorption of the yolk sac, zinc was found in future bony tissues at the onset of their mineralization. Dithizone apparently reveals only ionic zinc or zinc loosely bound in organometallic compounds.

1143. Sage, M. 1973. The relationship between the pituitary content of prolactin and blood sodium levels in mullet (Mugil cephalus) transferred from sea water to fresh water. Contrib. Marine Sci. 17:163-167.

Blood sodium levels in mullet adapting to a transfer from seawater to freshwater stabilized within 24 hours. There was no change in the mean prolactin concentration on the pituitaries at any time from 30 min to 6 weeks following transfer of fish from seawater to freshwater. Significant changes in the correlation of pituitary prolactin content with blood sodium and body weight were determined. Seawater fish have a pituitary prolactin content which shows no correlation with either body weight or blood sodium, whereas, in fish adapting to freshwater there is a negative correlation between prolactin and blood sodium as well as with body weight. In fish adapted to freshwater for one day or more there was a negative correlation of prolactin with blood sodium but no relationship to body weight. It is concluded that prolactin is involved both in the initial stages and the long term adaptation of mullet to freshwater.

1144. Saha, J.G. 1972. Significance of mercury in the environment: Suggestions for further research. In Radiotracer Studies of Chemical Residues in Food and Agriculture, Int. Atom. Ener. Agen., Vienna, Austria: 81-86.

Problems include more extensive measurements and more reliable analytical techniques; extent of contribution of burning fossil fuels to Hg received by earth's surface in rainfall; environmental factors affecting formation of highly toxic methyl Hg from other forms; sources of Hg pollution of water and their relative importance; and biochemistry of methyl Hg poisoning and its treatment. The dangerous Hg level in human blood is about 2000 ng/g; the level in about 80% of people without occupational exposure, less than 5 ng/g. Instances of local environmental poisoning include consumption of fish (which may show 300 times the concentration of the surrounding water), and of seed grain treated with mercurials.

1145. Saila, S.B. 1971. Mercury and marine fisheries. Community Health 3(3):129-132.

The information available suggests that natural levels of mercury in large predatory fishes are expected to be higher than in fishes with a shorter food chain. The health hazards from eating tuna or swordfish in normal amounts have probably been over-emphasized and the global problem may have been exaggerated. Although there are some who would strongly recommend a global monitoring system for mercury in the marine environment, it seems that the monitoring should be restricted to the vicinity of points of discharge of mercury-containing wastes. Mercury contamination of the marine environment and marine fishes is not considered to be a scientific problem at this time. The technological knowledge is already available to significantly reduce the quantity of mercury effluents released by industry and to replace the use of mercury compounds in agriculture with less toxic compounds.

1146. Salzinger, K., S.P. Fairhurst, S.J. Freimark, and F.D. Wolkoff. 1973. Behavior of the goldfish as an early warning system for the presence of pollutants in water. Jour. Environ. Systems 3(1):27-40.

Literature on effects of pollutants on fish, particularly goldfish, in terms of lethal dosage and behavioral changes are reviewed. Results are presented of an experiment showing effects of two very low concentrations of mercury on behavior of goldfish. Twelve goldfish were conditioned to form different behavior patterns to obtain food (three fish to each pattern). After stabilization of these patterns, one fish from each pattern was placed in mercury polluted water at a concentration of 10 μg/l, one at 6 μg/l, and a third in mercury-free water. All fish in 10 μg/l showed the largest drop in response rate. All but one of the fish in 6 μg/l showed greater decrease in response than those in 10 μg/l.

1147. Samilkin, N.S., and V.I. Vorob'ev. 1972. The influence of certain micro-elements on the development of white amur spawn. Rybnoe Khozyaistvo 8:29-31.

In experiments with incubating white amur (teleost) spawn, cobalt at less than 0.00025 mg/l or manganese at 0.0098-0.015 mg/l had no effect. Copper at 0.05 mg/l increased mortality of the larvae. Copper sulfate caused weakening and premature rupture of the egg membrane. Zinc sulfate yielded positive results at 0.05 and 0.1 mg/l; concentrations above 0.1 mg/l markedly inhibited normal swelling of the egg membrane. The number of normally developing embryos in comparison with controls increased by 16-18% on the average, with zinc sulfate doses of 0.05 and 0.01 mg/1 administered in the first 40 minutes of incubation.

1148. Samuels, E.R., M. Cawthorne, B.H. Lauer, and B.E. Baker. 1970. Strontium-90 and cesium-137 levels in tissues of fin whale (*Balaenoptera physalus*) and harp seal (*Pagophilus groenlandicus*). Canadian Jour. Zool. 48(2):2[illegible].

Strontium-90 and cesium-137, in eleven different tissues from fin whale and two tissues from harp seal were identified. The highest concentration of strontium-90 was found in whale blubber. Muscle tissue seemed to contain more cesium-137 than other tissues examined. The average concentration of cesium-137 in whale muscle was 4.5 pCi/g ash and in adult seal muscle this was 2.5 pCi/g ash.

1149. Sandholm, M., H.E. Oksanen, and L. Pesonen. 1973. Uptake of selenium by aquatic organisms. Limnology and Oceanography 18(3):496-499.

Fish muscle, plankton, aquatic plants, and meat meals were analyzed for selenium. The method was used in which 2,3-diaminonaphthaline is used as a fluorescing reagent and the recovery of Se is measured using Se-75 as a tracer. Cultured algae *Scenedesmus dimorphus* were used to study transfer of Se from water to phytoplankton. In some cases metabolic inhibitors (iodoacetamide, 1-methionine, KCN, 1-ethionine, 2,4-dinitrophenol) were used. The transfer of Se from selenite and selenomethionine to fishes was studied in aquaria. Phytoplankton which had taken up Se-75 were fed to zooplankton and finally the fish *Puntius aquaria*. The Se content was lowest in aquatic plants, varying from 0.02 to 0.14 mg/1 (dry wt), plankton samples contained from 1.1-2.4 mg/1, fishes cultured in ponds 0.5 to 0.9 mg/1, and fishes from natural environments 1.0 to 2.9 mg/1. The phytoplankter, *Scenedesmus dimorphus*, actively concentrated Se-selenomethionine but neither actively nor passively concentrated inorganic selenite. The zooplankton, consisting mostly of *Daphnia pulex*, absorbed Se from selenite. In aquariums fish concentrated only a small amount of organic or inorganic Se directly from water, but did concentrate Se from food.

1150. Sandifer, P.A. 1973. Effects of temperature and salinity on larval development of grass shrimp, *Palaemonetes vulgaris* (Decapoda, Caridea). U.S. Dept. Comm., Fish. Bull. 71(1): 115-123.

Larvae of *Palaemonetes vulgaris* were reared in the laboratory in a factorial experiment employing three temperatures (20°C, 25°C, and

30°C) and six salinities (5, 10, 15, 20, 25, and 30^{o}/oo). Temperature and salinity exerted significant effects on survival of larvae through metamorphosis. The temperature-salinity interaction was also significant. Lowest survival occurred in 5^{o}/oo at all temperatures. In higher salinities, survival at 20° and 25°C was similar (>60%) but was less at 30°C in most salinities. Temperature and salinity also influenced rate of larval development. Development at 20°C required nearly twice the time as that at 25° and 30°C, but a retarding influence of salinity was slight and evident only at low salinities (5 and 10^{o}/oo). Salinity and temperature-salinity interaction had no detectable influence on number of instars, but the effect of temperature alone was significant. Larvae reared at 25°C passed through fewer molts prior to metamorphosis than did those reared at 20° and 30°C. Comparing survival, rate of development and number of instars, optimal conditions for larval development occurred at a moderate temperature of about 25°C over a wide range of salinity (10 to 30^{o}/oo).

1151. Sangalang, G.B., and M.J. O'Halloran. 1972. Cadmium-induced testicular injury and alterations of androgen synthesis in brook trout. Nature 240(5382):470-471.

In fish exposed to 25 µg/l cadmium for 24 hours, testes were abnormally vascularized and discolored. The LC-50 for brook trout exposed to 10 mg/l Cd in a freshwater continuous flow system was found to be 21 days. In neither group was there damage to the primordial germ cells. In damaged testes, a reduction of lipid material indicated that androgen production might have been disturbed. Tissue from the damaged testes produced less 11-hydroxytestosterone and testosterone when incubated with radio-labelled pregnenolone than did control fish tissue. Biosynthesized labelled 11 ketotestosterone was detectable in control but not in the Cd-damaged tissue incubate. Analysis of normal testicular tissue incubated with varying amounts of cadmium showed that Cd-inhibited the conversion of exogenous pregnenolone to free steroids. Cadmium inhibited the biosynthesis of 11 DT from pregnenolone. Tissues incubated in high Cd levels exhibited a general reduction in product yields of 11 KT, 11 OHT and T.

1152. Saraswathy, M., and N.B. Nair. 1974. The influence of salinity on a tropical estuarine shipworm, *Nausitora hedleyi* Schepman (Bivalvia-Teredinidae). Hydrobiologia 44(4):397-411.

Species belonging to the genus *Nausitora* are generally confined to brackish waters. In the Cochin backwaters, a tidal estuary on the southwest coast of India, this genus is represented by *N. hedleyi*. Fresh settlement of the species in that area is noticed only during the period of low salinity. Tests conducted to ascertain effect of salinity changes on activity of the borer showed that though it can endure a wide range, the optimum salinity range for early development was from 11.24-14.54°/oo.

1153. Sawyer, P.J. 1970. The effects of copper sulfate on certain algae and zooplankters in Winnisquam Lake, New Hampshire. Available from Nat. Tech. Inf. Ser., Springfield, Va., as PB-196 481:1-28.

In a relatively unbuffered lake such as Winnisquam, control of cyanophycean blooms can be accomplished with relatively small amounts of copper sulfate—4 lbs/acre. Data on 27 algal species present before, during, and after addition of copper sulfate indicate that a rapid shift in species relationships occurred. Carbon fixation rate was found to be a more sensitive measure of bloom potential than cell counts. Susceptible species decreased in numbers; other forms increased in population; some appeared unaffected by treatment. The latter group may have been protected by natural resistance or by their position in the water column. Zooplankton reacted to copper treatment in various ways. The effects on microcrustaceans such as copepods and daphnids seemed to follow a predictable pattern. Copepods and *Bosmina longirostris* were more resistant than *Daphnia*. *Bosmina* multiplied to a concentration of 154/liter in the top meter of the water column. The rise and fall of numbers of species of plants and animals and their rapid response to conditions after copper sulfate treatment illustrate their complex relationships. The crude treatment with copper sulfate did produce control of an obnoxious blue-green alga, *Anabaena circinalis*.

1154. Schell, W.R., T. Jokela, and R. Eagle. 1973. Natural ^{210}Pb and ^{210}Po in a marine environment. *In* Radioactive Contamination of the Marine Environment, Int. Atom. Ener. Agen., Vienna, Austria: 701-724.

A regional sampling program has been initiated to determine existing levels of Pb-210 and Po-210 in sediment, organisms and water from different depths in a salt-water sound and a fresh-water lake. The collections have been made with plankton nets, midwater trawls, sediment corers, and a large volume water sampler consisting of 0.3 μm Millipore filters and Al_2O_3 sorption beds (200 to 2000 liters). The efficiency of collecting lead from fresh and salt water by the Al_2O_3 beds has been determined. The sample analysis was made using Po-208 tracer for yield determination and low background alpha spectroscopy which separates energies of Po-208 from Po-210; ingrowth and decay of Po-210 were used to determine Pb-210. Computer programs have been completed for data analysis, sorting, and retrieval. One interpretation of the early results of sample analysis from the fresh-water and salt-water environments is that the processes of erosion and leaching can contribute significantly to the concentration of Pb-210 and Po-210 in the aquatic environment. Regional differences are found which depend on the geological strata. Both the erosion process and the atmospheric fallout process must be considered as sources of these radionuclides in the aquatic environment. An unusually large concentration of Po-210 has been found in liver of a sablefish, Anoplopoma fimbria; the zooplankton in the same region also had a high Po-210 concentration. The nektonic crustacea have the highest Po-210/Pb-210 ratio (∿100) of the organisms collected.

1155. Schelske, C.L. 1973. Fallout ^{54}Mn accumulated by bay scallops Argopecten irradians (Lamarck) near Beaufort, North Carolina. In Radioactive Contamination of the Marine Environment. Int. Atom. Ener. Agen., Vienna, Austria: 331-346.

Scallops were collected in estuarine waters near Beaufort between Jan. 1963 and June 1966, and subsequently analyzed for gamma radioactivity originating from fallout. Most of the gamma radioactivity was Mn-54, with scallops containing 30 times more Mn-54 than other lamellibranch molluscs collected at the same time. Concentrations of Mn-54 were largest in Dec. 1963 and Oct. 1964 and declined after Oct. 1964, with a half-life of approximately 240 d. Concentrations of Mn-54 in the 75 samples collected were a function of collection sites in the estuary, size of the scallops, and tissue type. Amounts of Mn-54 were determined in seven different tissues. Kidneys contained the greatest concentrations, about 100 times more than adductor muscle, gills, mantle, gonad, visceral mass, and liquid. Maximum concentrations in kidneys were 100 pCi/g wet weight. Kidneys are a small fraction of the total weight, so concentrations in the combined soft parts are about a factor of 100 lower than the kidney. Stable element content of scallop tissues was determined also, and kidneys again contained at least 100 times more stable manganese than any of the other tissues. Variations in specific activities (pCiMn-54/μgMn) among the different tissues were greater than could be explained by physical decay and possible turnover rates in the organism. Mechanisms of Mn-54 and stable manganese accumulation are postulated from data on specific activity of different tissues, mode of scallop feeding, and results of laboratory experiments in which scallops were fed phytoplankton labelled with Mn-54. These data are important because kidneys of bay scallops concentrate Mn-54 more than any other biological system at present known. Public health implications are minimized because only the adductor muscle is sold as seafood.

1156. Schelske, C.L., D.A. Wolfe, and D.E. Hoss. 1973. Ecological implications of fallout radioactivity accumulated by estuarine fishes and mollusks. Presented at 3rd Nat. Symp. Radioecology, U.S. Atom. Ener. Comm. Rept. COO-2003-9:1-37.

Gamma-emitting radionuclides in estuarine organisms from near Beaufort, North Carolina, were measured. Fish samples taken from commercial catches were retained 2 years before measuring. Relatively high concentrations were: Cs-137 in nektonic feeding fish; Mn-54 in benthic feeding fish; Zn-65 in oysters; Mn-54 in bay scallops; and Ce-144 and Ru-106 in clams, mussels, and oysters. Of the 18 fish species studied, 5 were not measured since their radionuclide concentrations were relatively low. The differences in uptake between the different species are accounted for by differences in chemical composition, metabolism, and life cycle. These data show that knowledge of the physicochemical form of a radionuclide is required to predict its uptake.

1157. Schneider, J. 1972. Lower fungi as test organisms of pollutants in sea and brackish water. The effects of heavy metal compounds and phenol on *Thraustochytrium striatum*. Marine Biology 16:214-225.

Three test-series were applied, which differed in regard to the basal medium (natural or artificial sea water, salinity level, addition of detergent); the culture conditions (primary cultures, subcultures, back-innoculations into basal medium without toxic metals); the criterion employed (zoospore activity, sporangia development, or dry weight of *T. striatum*). The temperature applied was 18° to 20°C. The sea water-pollen-method (MWP) proved to be the most suitable: it is simple and more sensitive than the other tests; subcultures and back-inoculations are possible without much additional work; conditions stimulate nature; first results are available after 3 to 4 days. The SMS-method (enriched natural sea water of different salinities) provides additional information on salinity effects. Nine substances have been tested: $(CH_3COO)_2Hg$, $HgCl_2$, $CdCl_2 \cdot H_2O$, $ZnSO_4 \cdot 7H_2O$, $NiSO_4 \cdot 7H_2O$, $CuSO_4 \cdot 5H_2O$, $CoCl_2 \cdot 6H_2O$, $MnCl_2 \cdot 4H_2O$, and phenol. In regard to their toxicity these substances can be divided into 2 groups: Hg- and Cd-salts inhibit development down to greater dilutions than the remainder; Zn and Ni seem to yield intermediate effects. Salinity modifies the toxic effects of the test substances. In higher salinities, comparable concentrations of test substances reveal stronger inhibitory effects than in lower salinities. Detergents may augment the toxic effects, at least of $CuSO_4$. The marine lower fungus *T. striatum* is a useful organism for testing biological consequences of water pollutants.

1158. Schulz-Baldes, M. 1972. Toxicity and accumulation of lead in the common mussel *Mytilus edulis* in laboratory experiment. Marine Biology 16:226-229.

In studies conducted over 130 days, three batches of a total of 100 common mussels, Mytilus edulis, were maintained in media containing different lead concentrations. Two vessels served as controls. There was no acute injury to the mussels; but, over an extended period of time, a marked increase in mortality occurred which was related to lead concentration in the medium. The median lethal time (LT-50) was computed to be 218 days for the control, 150 days with 0.5 mg Pb/l in the medium, 129 days with 1 mg/l, and 105 days with 5 mg/l. Quantitative analyses of the soft parts of M. edulis by flameless atomic-absorption spectrophotometry revealed a distinct accumulation of lead. From a natural lead content of 8.4 μg Pb/g dry weight, the lead concentration increased to 12,840 μg/g at 0.5 mg/l, to 20,770 μg/g at 1 mg/l and to 39,830 μg/g at 5 mg/l. The ratio of the concentration of lead of the soft parts of M. edulis to the concentration in the medium remained in the same order of magnitude both under laboratory conditions using high lead concentrations and under in situ lead levels. Over a period of 130 days, lead uptake expressed as percentage of lead offered was 10.9% at 0.5 mg/l, 9.5% at 1 mg/l, and 3.4% at 5 mg/l, respectively.

1159. Schulz-Baldes, M. 1973. Die Miesmuschel, Mytilus edulis als Indikator fuer die Bleikonzentration im Weseraestuar und in der Deutschen Bucht. Marine Biology 21(2):98-102.

At 13 stations of the German Bight and Weser Estuary (in the Federal Republic of Germany) mussels were collected in 3 size categories: 14-16 mm, 21-23 mm, and 35-40 mm shell length. Equal numbers of the 3 groups from each station were analyzed separately for Pb concentration by flameless atomic absorption spectrophotometry. The Pb concentration of soft parts decreased from 6.4 μg/g dry wt at stations 15 km NW of Bremerhaven to 1.9 μg/g at Helgoland. At the same station, the concentration in small mussels is significantly higher than in larger mussels. The Pb concentration is high in kidney, intestine, and adductor muscle and low in foot, gills, and mantle with gonads. Mussels directly reflect the actual Pb concentration of their environment. The observed gradient in M. edulis in the Weser Estuary can be explained by the dilution of the Pb polluted river water by the seawater of the German Bight. Author suggests that M. edulis is highly suitable as an indicator organism for Pb and possibly other heavy metal pollutants.

1160. Schulz-Baldes, M. 1974. Lead uptake from sea water and food, and lead loss in the common mussel Mytilus edulis. Marine Biology 25:177-193.

Mussels were maintained for 6 weeks in sea water containing different concentrations of lead (0.005 to 5 mg/l). Lead concentration in soft parts was analyzed at different times during the experiment. A constant rate of lead uptake, linearly dependent on lead concentration of the medium, was observed. Rate of lead loss, measured after transferring mussels into natural sea water, is linearly dependent on the original lead concentration in the soft parts. Rates of uptake and loss in large mussels (shell length 45 to 55 mm, average dry weight 750 mg) are less than those in small mussels (shell length 19 to 21 mm, average dry weight 30 mg). During a more extended experimental period, adjustment to a steady state is expected to occur; rates of lead uptake and loss are then non-linear. Lead uptake by individual organs (kidney, gills, adductor muscle, digestive gland, foot, mantle with gonads) of large *M. edulis* was analyzed in 2 test series. In one series (medium) mussels were kept in a sea water medium containing 0.01 mg of Pb/1. In another series (food), the mussels were kept in natural sea water but fed with the green algae *Dunaliella marina* containing lead (approximately 600 µg/g dry weight). The lead quantity given per mussel per day was about 2 µg in both test series. Within 35 days, mussels from test series "medium" took up 29% of the total amount of lead given, those of test series "food" took up 23.5%. In all organs, lead concentration increased, but rates of uptake differed; kidney displayed by far the highest rate of uptake. A biologic calibration curve depicting the relationship between lead concentration in the soft parts at equilibrium with lead concentration in sea water, is presented.

1161. Scott, D.P., and F.A.J. Armstrong. 1972. Mercury concentration in relation to size in several species of freshwater fishes from Manitoba and northwestern Ontario. Jour. Fish. Res. Bd. Canada 29:1685-1690.

Statistical analysis of 53 samples of 11 species of fishes from a number of areas of Manitoba and northwestern Ontario indicated that in general there was a positive correlation between mercury concentration and length. There also appeared to be a more variable positive relation between mercury concentration and fish condition (fatness). It was possible to predict, for 31 of the 53 samples, the range of lengths within which there was a 95% probability of all fish containing less than 0.5 mg/kg mercury. However, within species the relation between mercury concentration and length was not consistent. The results show that, for certain of the populations closed to commercial fishing because of mercury contamination, selection (by fishing technique or otherwise) of certain sizes should provide fish of acceptably low mercury concentrations.

1162. Segar, D.A., J.D. Collins, and J.P. Riley. 1971. The distribution of the major and some minor elements in marine animals. Part II. Molluscs. Jour. Mar. Biol. Assn. U.K. 51:131-136.

A study has been made of the distribution of Fe, Mn, Co, Ni, Cd, Cu, Pb, Zn, Ag, Cr, Al, Na, K, Ca, Mg, and Sr in the shells and entire soft parts of 11 species of mollusca from the Irish Sea and in those of one freshwater species. Values are also presented for the occurrence of these elements in the various organs of *Pecten maximus* and *Modiolus modiolus*. All the trace metals are considerably more enriched in the soft parts of the organisms than in the marine environment. The highest concentrations of these elements are found in the digestive organs and gills, and the lowest concentrations are found in the shells.

1163. Sergeant, D.E., and F.A.J. Armstrong. 1973. Mercury in seals from eastern Canada. Jour. Fish. Res. Bd. Canada 30(6):843-846.

Mercury concentrations were measured in four species of seals having different migratory patterns and feeding ecology in order to clarify to some extent the distribution of mercury in the ocean and concentrations through the food chain. Mercury concentrations were highest in liver (usually 1-100 mg/kg but up to 387 mg/kg) and lowest in blubber (usually 0.1 mg/kg). Levels in muscle ranged from less than 0.16 to 2.35 mg/kg. Values similar to those in muscle were found in the few specimens of heart, intestine, and lungs analyzed and higher values in kidney and hair. Ratios of mercury in liver to that in muscle for adult seals were much greater than those found in two species of freshwater fish and three species of domestic animals exposed to wide ranges of mercury concentrations in their food. Mercury in seals increased with age and appeared to vary with the position in the marine food web of the organisms which they eat. Harp seals (*Pagophilus groenlandicus*), which feed on small pelagic fish and crustaceans, accumulated an order of magnitude less mercury than grey (*Halichoerus grypus*) and harbor (*Phoca vitulina*) seals, which live on large pelagic and benthic fish and cephalopods. However, grey and harbor seals are resident in eastern Canadian waters, which presumably contain higher mercury levels than arctic waters, where harp seals spend about half the year. Yet hood seals (*Cystophora cristata*), which spend more than half the year in arctic waters but feed on large fish and cephalopods, had mercury levels as high as grey and harbor seals.

1164. Seymour, A.H. 1963. Radioactivity of marine organisms from Guam, Palau and the Gulf of Siam, 1958-1959. *In* Schultz, V., and A.W. Klement, Jr. (eds.). Radioecology. Reinhold Publ. Corp., New York: 151-157.

Following the Hardtack weapons test series at Bikini and Eniwetok in 1958, samples of fish, crabs, lobsters, snails, clams, algae, and plankton were collected at Guam, Palau, and in the Gulf of

Siam for radiological analyses. The collecting areas were 1800, 2900, and 6400 kms, respectively, west of the test site. The gross beta activity was determined for all samples and the gamma-emitting nuclides were identified in selected samples.

The rate of westward transport of local fallout from the Hardtack series by the North Equatorial Current was estimated at 12 kms per day between the test site and Guam and Palau. The criterion for arrival of fallout at collecting area was a significant increase in gross beta count of certain biological samples. Levels of radioactivity were considerably different for samples from the three collecting areas: the counts of samples from Guam were notably higher than those from Palau, which in turn were very much higher than those from the Gulf of Siam, which were essentially at background level for all collections. The gross beta counts of fish muscle from all areas from all collections were constant and less than seven μμCi/g wet wt. Samples with the highest gross beta counts were clam kidney and spider snail liver, with maximums of 204 and 356 μμCi/g, respectively. Gross beta counts of some Guam and Palau samples prior to the arrival of the Hardtack fallout indicate the presence of radionuclides from prior test series. Gamma-emitting nuclides other than naturally occurring potassium-40 included, in order of abundance, cobalt-57, cobalt-60, manganese-54, cerium-144, zinc-65, and silver-110m. The greatest value was 2,300 μμCi/g wet wt for clam kidney (Tridacna). The occurrence of silver-110m in the liver of the spiny lobster was of special interest because it is a previously unreported fallout nuclide and so far has been detected only in spiny lobster "liver." Additional information on radionuclides to be expected in marine organisms from the western Pacific can be found in the report of the Hanford Laboratories in Richland, Wash. on the radionuclide analyses of samples collected after the 1956 Redwing test series.

1165. Seymour, A. (ed.) 1971. Radioactivity in the marine environment. Nat. Res. Counc., Nat. Acad. Sci., 2101 Constitution Ave., Wash. D.C.:1-272.

This volume summarizes much of what is useful regarding physical, chemical, geological, biological and ecological aspects of radioactivity in marine waters, sediments and biota. A list of about 1200 references is appended.

1166. Seymour, A.L. 1971. Columbia River studies annual progress (1970-1971). Available from Nat. Tech. Inf. Ser., Springfield, Va., as RLO 2225-T-1-8:1-12.

Hanford-produced radionuclides were monitored in the field, and effects of radiation and temperature stresses upon oyster larvae and phytoplankton were evaluated in the laboratory. Several projects are reported, some of which are described in greater detail in separate reports: (Biological half-life for Zn and Hg in oysters, RLO-2225-T-1-5, May 1970, 20p; Rate of loss of mercury by Pacific oysters, RLO-2225-T1-6, Feb. 1971, 10p; Radiological aspects of nuclear power and the aquatic environment, RLO-2225-T1-1, 1969, 15p). Author lists estimates of concentration factors for diatoms and Sc-46 (2000), Zn-65 (510), Zr-95 + Nb-95 (1300). A concentration factor for razor clam and Zn-65 is 3300. The radiation dose from sediments results from naturally occurring radionuclides for the most part.

1167. Seymour, A.H., and V.A. Nelson. 1973. Decline of ^{65}Zn in marine mussels following the shutdown of Hanford reactors. In Radioactive Contamination of the Marine Environment, Int. Atom. Ener. Agen., Vienna, Austria: 277-286.

The shutdown of the last of eight original plutonium production reactors at the Hanford Atomic Plant in February 1971, eliminated the source of practically all radionuclides in the Columbia River and in the plume of Columbia River water in the Pacific Ocean. Zinc-65, perhaps the most biologically important of the Hanford-produced radionuclides in the marine environment, continues to be present in both biota and water 15 months after shutdown. The amounts of Zn-65 in mussels at the mouth of the Columbia River and along the Washington Coast have been monitored since 1961, and data from these observations have been used as reference values to measure the loss of Zn-65 related to shutdown of reactors. The amount of Zn-65 in soft tissues of Mytilus edulis from the North Jetty at the mouth of the Columbia River declined from 40 pCi/g of dry tissue in February 1971, to 6 pCi/g, dry, in May 1972. The effective half-life for Zn-65 was calculated to be 130 d and the loss of Zn-65 by processes other than physical decay, in terms of half-life, was calculated to be 277 d. The latter value is called ecological half-life rather than biological half-life, since there is some uptake of recycled Zn-65 but at a rate less than the rate of loss of Zn-65 by biological processes. At North Head, 5 km north of the Columbia River, the amount of Zn-65 and Zn in M. californianus and the rate of decline was less than comparable values for North Jetty mussels, although the specific activity values, µCi Zn-65/g Zn, for mussels from both locations, collected on the same day, were similar. The Zn-65 effective half-life value for North Head mussels was 149 d. The amount of Zn-65 in mussels from seven locations on the Washington Coast and in the Strait of Juan de Fuca, to a distance of 340 km from the Columbia River, declined in a regular manner in respect both to distance from the Columbia River and to time after reactor shutdown.

1168. Shannon, L.V., and R.D. Cherry. 1967. Polonium-210 in marine plankton. Nature 216:352-353.

Little work appears to have been done on polonium-210 or lead-210 in the marine environment. The present account established general levels of polonium-210 in marine plankton samples obtained from the seas around the Cape of Good Hope during 1965 and 1966. An in vivo (wet plankton) concentration of about 200 pCi/kg was determined. The unsupported polonium-210 activity in plankton samples is thus more than an order of magnitude greater than the total polonium-210 reported in human soft tissues. There is a tendency for offshore samples to contain higher unsupported polonium-210 activity than samples collected nearer shore. A possible explanation could lie in the fact that much of the inshore surface water off the west coast of the Cape of Good Hope is upwelled water of Atlantic central water origin. Such water has, in general, less time in contact with the atmosphere than the subtropical surface water found further offshore; because the polonium-210 is presumably derived chiefly from atmospheric fallout a lower polonium-210 content in the inshore waters seems reasonable.

1169. Sharp, R.W. 1971. Road salt as a polluting element. In Street salting. Urban Water Quality Workshop Proc., State Univ. Coll. of Forestry at Syracuse Univ., May 6, 1971: Syracuse, N.Y., State College of Forestry: 70-73.

The use of salt for snow and ice control on northern streets and highways has grown rapidly since the 1940's. In the winter of 1964-65, the City of Milwaukee, Wisconsin, used 33,000 tons of sodium chloride and 200 tons of calcium chloride. In the same winter, the Wisconsin Highway Department used 160,000 tons of sodium chloride, or 15.8 tons per mile of highway. The chlorides, being highly soluble, are carried by runoff water to lakes and streams. The question arises as to possible damage to the aquatic and terrestrial environment. Environmental effects appear to be localized near large urban centers and along heavily used freeway routes. Diamond Lake, in Hennepin County, Wisconsin, which receives the discharge of a major storm sewer, now has a chloride content of 2,270 mg/l, equivalent of 3,780 mg/l sodium chloride. To place these values in the perspective of fish tolerance, bluegills will tolerate 10,000 mg/l sodium chloride. Rainbow trout sustained 20% mortality at 12,000 mg/l. A build-up of sodium chloride can cause complete soil sterility. Studies show a substantial build-up in chloride content of domestic wells located adjacent to main highway systems. Chloride levels exceeding the potable water supply standard of 250 mg/l have been found in many states during recent years as a result of road salt application.

1170. Shaw, T.L., and V.M. Brown. 1971. Heavy metals and the fertilization of rainbow trout eggs. Nature 230(5291):251.

Results of preliminary tests on effects of copper and nickel on fertilization of rainbow trout eggs show that neither element is likely to be responsible for any impairment of fertilization among trout at existing natural levels. This does not imply that successful development would occur under conditions of continuous exposure to these poisons.

1171. Shaw, W.H.R., and B. Grushkin. 1957. The toxicity of metal ions to aquatic organisms. Arch. Biochem. Biophys. 67(2):447-452.

Experimental results (guppies, toad tadpoles) and data collected from the literature (protozoa, cladocera, fish) on toxicity of cations (Mn, Co, Ni, Zn, Pb, Cd, Cu, Ag, Hg) to aquatic organisms are presented. The findings are analyzed in terms of a model based on the Michaelis-Menten mechanism and on the assumption that the cations considered are toxic because they combine with an essential sulfhydral group attached to a key enzyme.

1172. Shealy, M.H., Jr., and C.A. Carlson. 1971. Accumulation and retention of strontium-85 marks by young largemouth bass. _In_ Radionuclides in Ecosystems, Proc. Third Nat. Symp. Radioecol.: 307-317.

First-year mortality in largemouth bass, _Micropterus salmoides_, is often higher than 90%. To better understand the role of predation by aquatic invertebrates in this high death rate, young bass were marked at four different ages with Sr-85 for subsequent use in predation studies. Resulting radiostrontium accumulation and retention curves indicate that this radionuclide is suitable for quantitative marking of prolarval, postlarval, and juvenile bass, but not embryos. Bass embryos were exposed to one, and prolarval and older stages to three Sr-85 concentrations at 20 to 23°C. Exposure energies ranged from 0.0 (controls) to 89.1 μCi/l of pond water. Twelve-hour radioaccumulation and retention rates were obtained for embryos (2 days old). Authors monitored radioaccumulation in prolarvae (<1 day old) at 12-hr intervals from 12 to 168 hr, in postlarvae (15 days old) at 24-hr intervals from 24 to 144 hr, and in juveniles (40 days old) at 24-hr intervals from 24 to 120 hr. Bass from all accumulation experiments were transferred, after various periods of exposure, to pond water to which no Sr-85 was added, and mark retentions were evaluated for periods of up to 106 days.

1173. Sheets, W.D. 1957. Toxicity studies of metal-finishing wastes. Sewage Ind. Wastes 29:1380-1384.

Concentrations of various compounds required to affect bacterial biological oxygen demand values by 50% in buffered synthetic sewage media were: CrO_3, 4 mg/l; K_2CrO_4, >50; $CrCl_3$, 0.23; H_2SiF_6, >50; $NiSO_4 \cdot 6H_2O$, 16; $Al_2(SO_4)_3$, 18; $CuSO_4$, 0.4; and $AgNO_3$, 0.3 mg/l. Tests conducted in unbuffered media produced values that were 1/2 to 1/25 those conducted in buffered media. Mixtures of Cr-Cu, Cu-Ni, and Cr-Cu-Ni reacted antagonistically, but Cr-Ni mixtures had a definite synergistic trend.

1174. Shimizu, M., T. Kajihara, and Y. Hiyama. 1970. Uptake of ^{60}Co by marine animals. Records of Oceanographic Works in Japan 10(2):137-145.

Tracer experiments using Co-60 were conducted to determine uptake and concentration factors of Co by marine animals. Organisms used were: *Styela plicata* (sea squirt), *Mytilus edulis* (mussel), *Leander pacificus* (shrimp) and *Clibanarius virescens* (hermit crab). Concentration factors over a 15-30 day period were: *S. plicata*, viscera 850, test 400; *M. edulis*, soft body 140, shell 190; *L. pacificus*, flesh 5, carapace 18; and *C. virescens*, whole body 520.

1175. Shimizu, M., T. Kajihara, I. Suyama, and Y. Hiyama. 1971. Uptake of ^{58}Co by mussel, *Mytilus edulis*. Jour. Radiation Res. 12(1):17-28.

Uptake of Co-58 was determined by tracer experiments using mussel, *Mytilus edulis*, which has a world-wide distribution and is considered to be a sufficiently reliable indicator organism of radioactive contamination of the marine environment. For soft tissues, accumulation was high in alimentary tract, and low in mantle and adductor muscle. High concentration factors in byssus (1,500) and shell (190) were noticeable. By means of immersion experiments with shell pieces and cut off pieces of byssus in Co-58 containing seawater, it was concluded that high accumulation of Co-58 by byssus and shell was due to surface adsorption. Discussions are given on the utility of mussel as an indicator organism and on the role of structural protein of shellfish in the adsorption of radionuclides.

1176. Short , Z.F., P.R. Olson, R.F. Palumbo, J.R. Donaldson, and F.G. Lowman. 1971. Uptake of molybdenum, marked with ^{99}Mo, by the biota of Fern Lake, Washington, in a laboratory and a field experiment. *In* Radionuclides in Ecosystems, Proc. Third Nat. Symp. Radioecol. 1:474-485.

The bioaccumulation of molybdenum, marked with Mo-99, was followed in month-long studies in an aquarium, where water, not food, was the major source of the nuclides, and in Fern Lake, where assimilation by organisms isolated in live-boxes was compared with assimilation by those with access to their usual sources of food. In the aquarium containing 3.3 mg/l of the metal, the alga *Nitella flexilis* accumulated up to 130 mg/kg molybdenum, a "luxury" amount. In Fern Lake, with 0.014 µg/l, the maximum concentration in the *N. flexilis* was 8.8 µg/kg. Uptake in the lake was irregular because of local chemical conditions in the water. The concentration in periphyton from the lake shoreline reached 50 µg/kg.

All tissues dissected from clams, crayfish, and trout in the aquarium contained some molydbenum. In trout the least amounts were in the gastrointestinal tract. In the lake, small amounts were in a few trout held without food in the live-boxes, but concentrations were up to 16 µg/kg in the gastrointestinal tract and liver of fish which were free to feed. The concentrations in the liver of fingerlings exceeded that in the yearlings by a factor of 4.

1177. Silver, M., and A.E. Torma. 1974. Oxidation of metal sulfides by *Thiobacillus ferrooxidans* grown on different substrates. Canad. Jour. Microbiol. 20(2):141-147.

Thiobacillus ferrooxidans, grown on either ferrous sulfate, lead sulfide concentrate, or chalcopyrite concentrate demonstrated oxygen uptake and CO_2 fixation in the presence of ferrous sulfate, chalcopyrite ore, pyrite ore, and red antimony trisulfide. Lead sulfide-grown cells could oxidize lead sulfide ore and galena, using the energy obtained for CO_2 fixation. All three cell types could oxidize nickel sulfide, but could not fix CO_2 in the presence of this substrate. Solubilization of metals from substrates and crystallographic changes in insoluble residues are reported.

1178. Silvey, W.D., and G.A. Irwin. 1969. Relation of water quality to striped-bass mortalities in the Carquinez Strait of California. U.S. Geol. Surv., Open-File Rep., Mar. 20, 1969: 1-12.

No direct quantitative relations were found to indicate the cause of striped-bass mortalities in the Carquinez Strait area, California. Several possible causes of the mortalities were considered but could not be proven. Industrial effluents were considered as a possible cause of mortalities, but evidence was not found to show this possibility. Heavy metals (zinc, lead, and chromium) were analyzed but not found in large concentrations. Copper was found throughout the entire estuary in concentrations of about 0.10 mg/l. If copper was the responsible agent, the mortalities would have been widespread throughout the estuary, but they were not. Mortalities did not occur as a result of spawning. The lack of osmoregulatory adaptation to the sharp salinity gradient in Carquinez Strait is not a major cause of the mortalities. One major probable cause of the mortalities was natural hydrogen sulfide production. Large concentrations of biologically produced hydrogen sulfide were found on and in mudflats in Carquinez Strait at the time of the mortalities peak. Although this alone does not prove a direct cause and effect relation, biologically produced hydrogen sulfide, a natural phenomenon, is the most likely cause of striped-bass mortalities in Carquinez Strait.

1179. Sinha, E 1972. Metals as pollutants in air and water. Ocean Engin. Infor. Ser. 6:1-85.

This bibliography contains 583 abstracts of the worldwide literature providing substantial scientific and technological information on: detection, analysis and measurement of metals as pollutants in air and water; domestic, industrial, urban and other sources; the biogeochemical and meteorological processes involved in the distribution of the pollutants; effects on human health, experimental and test animals, and various other life forms; and standards and controls. In addition to a bibliography of bibliographies, a keyterm index supplements a detailed subject outline. It is intended as an interdisciplinary guide to studies of metals as pollutants.

1180. Skerfving, S. 1972. Mercury in fish: Some toxicological considerations. Food Cosmet. Toxicol. 10(4):545-556.

A literature review including animal experiments, metabolism of methylmercury and toxicity levels in man, and actions by various governments is presented.

1181. Skidmore, J.F., and P.W.A. Tovell. 1972. Toxic effects of zinc sulfate on the gills of rainbow trout. Water Research 6(3): 217-230.

Initial changes that occur in gill tissue of rainbow trout exposed to 40 mg/l of Zn^{2+} are typical of an acute inflammatory reaction. Epithelium covering the secondary lamellae lifts away in a continuous sheet from the pillar cell system, increasing the diffusion distance from water to blood. Blood flow patterns through the lamellae change, granulocytes appear in large numbers within the lamellar blood spaces and beneath the raised epithelium. Finally the lamellar blood circulation stagnates, terminating in respiratory collapse and death of the animal. The dynamics of blood flow during the progressive stages of gill damage are discussed.

1182. Slonim, A.R., and F.C. Damm. 1972. Beryllium uptake by the common guppy using radioisotope Be-7. II. Beryllium concentration in fish. Report AMRL-TR-72-95:1-25. Available from Nat. Tech. Inf. Ser., Springfield Va., as AD-758 815.

Two bioassays were conducted in which radioactive beryllium, Be-7, was added as a tracer to beryllium sulfate solutions in order to obtain some insight into beryllium toxicity in fish. Bioassays indicated that amount of beryllium concentrated within the guppies (and fry) was influenced by beryllium concentration in solution and by fish size (inversely), and to a lesser extent by exposure period. Factors not affecting uptake were age of fish and water hardness. Generally, Be uptake varied substantially among fish exposed to the same environmental conditions. Examination of individual tissues and organs of 6 guppies showed that most Be concentrated in viscera and that uptake was highest (per total organ) in gastrointestine and kidney of the 9 organs analyzed provisionally. These studies suggest that lethality of beryllium in fish is not dependent upon amount concentrated within the fish, but more likely on effect of beryllium on a particular target organ, cellular or subcellular component.

1183. Slonim, C.B., and A.R. Slonim. 1973. Effect of water hardness on the tolerance of the guppy to beryllium sulfate. Bull. Environ. Contamin. Toxicol. 10(5):295-301.

Acute toxicity bioassays were conducted with $BeSO_4$ and guppies. Four static tests were conducted simultaneously with four levels of hardness (22, 150, 275, 400 mg/1) and Be concentrations ranging from 0.1 to 60 mg/1. In addition, two subsequent bioassays were conducted to assess the hypothetical relationship between the LC-50 and water hardness. LC-50 (96 h) values were 20.0 mg Be/1 at 400 mg/1 hardness, 13.7 mg Be/1 at 275 mg/1 hardness, 6.1 mg Be/1 at 150 mg/1 hardness, and 0.16 mg Be/1 at 22 mg/1 hardness. Curves resulting from plots of percent survivors vs. Be concentrations show downturns as water hardness is lowered. In hard water, LC-50 values did not change significantly after 24-hr exposures, but in soft water they were significantly lower from 24- to 96-hr exposures. Equations are included which can be used to estimate toxicity of $BeSO_4$ to guppies at any given water hardness.

1184. Small, L.F., S.W. Fowler, and S. Keckes. 1973. Flux of zinc through a macroplanktonic crustacean. In Radioactive

Contamination of the Marine Environment. Int. Atom. Ener. Agen., Vienna, Austria: 437-452.

A simple, linear model has been employed for an heuristic examination of the flux of zinc through the euphausiid *Meganyctiphanes norvegica* in the Mediterranean Sea. The model is generated from the basic equation $k_e=\mu_e+\lambda_e$, where k_e is the rate of ingestion of particulate zinc by the euphausiid, μ_e is retention of the element in newly elaborated body tissue, and λ_e is the rate of elimination of the element. For a first approximation, the k_e term is assumed to apply only to ingestion of particulate zinc, though the model can also be made to incorporate direct uptake of zinc from solution. The k_e term breaks down into $k_e=(Q_i\rho_i)$, where Q_i = zinc concentration in ingested food and ρ_i = ingestion rate. The μ_e term is equivalent to $(Q_g\rho_g)$, where Q_g = zinc concentration in new tissue added in growth, and ρ_g = growth-rate. The λ_e term, which really sets the flux of zinc through *M. norvegica*, can be fractionated as $\lambda_e=(Q_f\rho_f)+(Q_m\rho_m)+(Q_c\rho_c)+(Q_x\rho_x)+\rho_e$, where Q_f, Q_m, Q_c, and Q_x are zinc concentrations in faeces, moults, dead carcasses, and non-viable eggs, respectively, and ρ_f, ρ_m, ρ_c, and ρ_x are the respective rates of product. The ρ_e term accounts for excretion of dissolved metabolic productions. Over the life span of *M. norvegica* some of the terms are discontinuous (ρ_x, for example), and all are non-linear. Therefore, authors have selected "ecologically significant" segments of the life span (segments representing most of the impact on zinc flux, from biomass estimates), and have summed linear approximations of these selected segments. Using adult animals feeding and defecating for 12 h each day, maximum λ_e estimates (126.61 μgZn lost/g dry weight/day) plus maximum μ_e estimates (4.38 μgZn retained/g dry weight/day) yielded a maximum estimate for k_e (130.99 μgZn ingested/g dry weight/day). Similarly, near-minimum estimates of λ_e and μ_e gave a near-minimum estimate of k_e (51.22 μgZn/g dry weight/day). The Zn concentration in the food of *M. norvegica* was calculated to be approximately 400-450 μgZn/g dry weight to satisfy the elimination and growth terms. Measured Zn concentration in "natural" foods of the euphausiid averaged 570 μgZn/g dry, an estimate reasonably close to the calculated concentration. The Zn budget in *M. norvegica* is thus adequately described, and indicates that faecal pellet deposition $(Q_f\rho_f)$ is the most significant term (representing over 90% of the Zn flux). Applicability of the above approach, and the most sensitive parameters, are discussed relative to other elements and other organisms.

1185. Smith, F.A., R.P. Sharma, R.I. Lynn, and J.B. Low. 1974. Mercury and selected pesticide levels in fish and wildlife of Utah: II. Levels of mercury, DDT, DDE, dieldrin and PCB in chukars, pheasants and waterfowl. Bull. Environ. Contamin. Toxicol. 12(2):153-157.

Levels of mercury and selected pesticides were determined in muscle tissue of chukars, pheasants and waterfowl collected from various regions within the state of Utah. None of the chukar tissue, 6% of the pheasant tissue and 4% of the waterfowl tissue analyzed contained mercury concentrations greater than the FDA limit of 0.5 mg/kg. None of the chukars or pheasants and only 2% of the waterfowl inspected contained dieldrin concentrations above the FDA tolerance level of 0.3 mg/kg. None of the chukars or pheasants contained levels of DDT + DDE above 5.0 mg/kg FDA tolerance level. The majority of the waterfowl tissue contained levels of PCB's higher than selected pesticide levels. No definite relationship between the levels of mercury and pesticides or PCB's was noted.

1186. Smith, E.J., J.L. Sykora, and M.A. Shapiro. 1973. Effect of lime neutralized iron hydroxide suspensions on survival, growth, and reproduction of the fathead minnow (*Pimephales promelas*). Jour. Fish. Res. Bd. Canada 30:1147-1153.

The long-term effect of lime-neutralized suspended iron on fathead minnow survival, growth, and reproduction was assessed in a flow-through environment with a modified proportional diluter. Results of 12 months of testing reveal lower survival and declining growth of fathead minnows with an increase in lime-neutralized suspended iron concentration. Hatchability and growth of fathead minnows were appreciably reduced in the lowest insoluble iron concentration tested of 1.5 mg Fe/l. Reduced hatchability was attributed to the higher percentage of smaller particles in low lime-neutralized iron concentrations. A comparison of data on survival, growth, and hatchability indicates that the safe level of suspended iron for fathead minnows presumably lies between the control and 1.5 mg Fe/l.

1187. Smith, W.G. 1970. Spartina "die-back" in Louisiana Marshlands. Coastal Studies Bull. 5:89-96.

Conditions causing degeneration and death, or "die-back," of large areas of marsh grass, *Spartina alterniflora*, in Louisiana and elsewhere in the United States are compared to those affecting *Spartina townsendii* marshes in England. Specific causative factors in the Louisiana die-back include: periods of excess salinity, waterlogging in poorly drained sites, parasitism, lack of available iron, hydrogen sulfide toxicity, oxygen deficit in roots, change of tidal regime, and pollution effects.

1188. Snekvik, E., and M. Grande. 1970. Pollution problems in fresh water fishing in Norway. Nor Vet Tidsskr. 82(4):180-182.

Pollutants affecting Norwegian fresh waters include paper mill and wood-working industrial wastes, containing sulfite and other chemicals, and wood fibers. Mercury from paper mills and pulp mills has led to high Hg concentrations in fish. Pyrite mine wastes, containing acid solutions of Cu and Zn were also found. The softness of Norwegian fresh water, 4-15 mg CaO/1, increases the lethal effect of heavy metals on fish. Pesticides, agricultural wastes, and synthetic detergents are also contributors.

1189. Somayajulu, B.L.K., and Rama. 1972. Mercury in sea-food from the coast off Bombay. Current Science 41(6):207-208.

Specimens of common seafood, including lobster, pomfret, Bombay duck and prawns were collected off the coast of Bombay, India, and analyzed for mercury content. Neutron activation and beta-gamma coincidence counting were used to measure mercury levels. Results of the testing indicate a mercury concentration of about 100 μg/kg for all analyzed organisms, except salmon, which evidenced higher levels. The upper limit of mercury allowed by U.S. Food and Drug Administration is 500 μg/kg; the samples all fell considerably below that limit.

1190. Spangler, W.J., J.L. Spigarelli, J.M. Rose, and H.M. Miller. 1973. Methylmercury: Bacterial degradation in lake sediments. Science 180(4082):192-193.

During the first 50 days of a long-term period of incubation of lake sediments with inorganic mercury (Hg^{2+}), low concentrations of methylmercury were observed to build up. Upon continued incubation there was a rapid decrease in amount of methylmercury in the system and a concomitant evolution of volatile inorganic mercury (Hg^0). Transfer of the mixed culture to growth media containing methylmercury resulted in the degradation of methylmercury and the volatilization of Hg^0. Four bacterial isolates were obtained from the mixed culture which, in pure culture, rapidly degraded methylmercury to methane and Hg^0. The presence of methane in head space gases was confirmed by flame-ionization gas chromatography, and the presence of Hg^0 in head space gases was confirmed by mass spectrometry.

1191. Sparks, R.E., J. Cairns, Jr., and A.G. Heath. 1972. The use of bluegill breathing rates to detect zinc. Water Research 6: 895-911.

The presence of zinc at concentrations of 8.7, 5.22, 4.16 and 2.55 mg/1 in dechlorinated municipal tapwater was detected by an increase in breathing rate or a change in breathing rate variance of bluegills. None of the fish exposed to the three lower concentrations died during the experiments. The criterion for detection was an arbitrary number of responses occurring at the same time. When the criterion was changed from a single response to three responses occurring at the same time, the number of false detections ("detections" occurring before zinc addition) decreased, but the lag between zinc addition and detection increased. Zinc concentrations of 0.035 and 0.076 mg/l (approximately 1/75 and 1/34 of 2.55 mg/l, respectively) did not appear to affect reproduction and growth of bluegills in the laboratory, but 0.235 mg/l zinc (approximately 1/10 of 2.55 mg/l) inhibited spawning in ripe bluegills and killed newly-hatched fry.

1192. Sparks, R.E., J. Cairns, Jr., R.A. McNabb, and G. Suter II. 1972. Monitoring zinc concentrations in water using the respiratory response of bluegills (Lepomis macrochirus, Rafinesque). Hydrobiologia 40(3):361-369.

Measuring the cough frequency of bluegills by means of a cannula inserted through the snout into the buccal cavity is a good monitoring technique for zinc (and probably other heavy metals) because the response is quick, proportional to the toxicant concentration, and occurs at sublethal concentrations.

1193. Sparks, R.E., W.T. Waller, and J. Cairns, Jr. 1972. Effect of shelters on the resistance of dominant and submissive bluegills (Lepomis macrochirus) to a lethal concentration of zinc. Jour. Fish. Res. Bd. Canada 29:1356-1358.

When pairs of bluegills were kept in bare, 40-l compartments for 5 days, dominant-submissive relations developed, and the dominant fish survived a subsequent exposure to 32 mg/l zinc longer than submissive fish. A flowerpot shelter in each compartment reduced the number of aggressive encounters between fish and removed the response difference. These results indicate that dominant-submissive relations may be a source of variability in the results of bioassays that use fish.

1194. Spigarelli, S.A. 1971. Ecological factors affecting the accumulation of cesium-137 fallout by a natural population of largemouth bass (Micropterus salmoides). In Radionuclides in Ecosystems. Proc. Third Nat. Symp. Radioecol. 1:328-333.

Individual fish characteristics (sex and weight), monthly precipitation, and time of year were statistically analyzed for their influence on Cs-137 activities of largemouth bass collected from Wintergreen Lake, Kalamazoo County, Michigan. Monthly collections of bass were analyzed for Cs-137 activity. No significant difference in Cs-137 activity was detected between male and female bass of equal size. However, body weight was a significant factor; larger bass accumulated more Cs-137 and total Cs per unit weight than small bass. The plots of Cs-137 vs. weight and total Cs vs. weight were very similar and supported the specific activity concept. The relationship between weight and Cs-137 in bass was estimated to be curvilinear with positive slope up to approximately 1000 g and negative slope above 1100 g.

Mean Cs-137 activities of bass collected monthly from May to October 1969 were significantly different. The maximum activities occurred during May, the minimum in August. No correlation was demonstrated between monthly precipitation levels and Cs-137 activities of bass.

1195. Sprague, J.B. 1968. Promising anti-pollutants: Chelating agent NTA protects fish from copper and zinc. Nature 220(5174): 1345-1346.

Copper and zinc are widespread pollutants both in industrial areas and wilderness areas. A chelating agent, nitrilotriacetic acid (NTA) appears to be a promising short-term anti-pollutant. Bioassays involving copper and zinc, alone, in mixtures, and in combination with NTA were carried out on brook trout over periods of ten days, the fish being maintained under conditions otherwise considered optimum for the species. Individual times of death were recorded and lethal thresholds (in milligrams/liter) were obtained for copper (0.05) and zinc (0.75). Thresholds were given a 'toxic unit value' of 1.0. Addition of NTA caused a decrease in toxicity (longer survival of fish) at most concentrations of metals (up to 330 toxic units). NTA chelates, at ratios of 1 molecule NTA: 1 ion metal, selectively chelates copper before acting upon zinc. NTA is apparently as effective as EDTA and costs less. Tabular material gives selected results of mixed copper-zinc toxicity trials, with and without NTA.

1196. Spronk, N., F.G. Brinkman, R.J. Van Hoek, and D.L. Knook. 1971. Copper in Lymnaea stagnalis L. II. Effect on the kidney and body fluids. Comp. Biochem. Physiol. 38A:309-316.

Snails were exposed to 0.00005 M $CuSO_4$ solutions (about 3.2 mg Cu/l). This caused losses of about 30% Na and Cl in their kidneys, with a parallel increase in copper content of about 40%. The concentration of bromine also increased. Kidney tissue was analyzed using neutron activation techniques. Increased water content of kidneys after the $CuSO_4$ treatment is explained by increased water influx from body fluids and less effective Na exchange.

1197. Srivastava, A.K., and G.E. Pickford. 1972. Effects of hypophysectomy on the blood serum of male killifish, Fundulus heteroclitus, in salt water. Gen. Comp. Endocrinol. 19:290-303.

Determinations were made of serum osmolality, major serum electrolytes and selected organic constituents in microliter samples of blood of parallel groups of hypophysectomized and mock-operated male killifish, maintained in salt water for 14-15 wk under standard conditions (ca. 20°C, 8 hr/day light, and daily feeding). Stress was minimized by "training" before autopsy. Although hypophysectomized killifish appeared to regulate the total serum osmolality, there was a marked decline in serum Na^+ (-7.9%), serum Cl^- (-18.2%), and, among minor electrolytes serum inorganic PO_4^{2-} (-45.3%). These decreases were offset, in part, by increases in serum Ca^{2+} (9.7%), serum Mg^{2+} (19.8%) and serum HCO_3^- (71.9%). Serum K^+ was variable, and the trend to increase was not significant.

Hypophysectomy caused a significant decrease in serum glucose (-31.9%). Serum urea was more than doubled (129.2%), but the osmotic contribution remained small. Serum total protein levels rose significantly (46.4%), although only low mobility fractions were affected. In spite of the decrease in serum inorganic PO_4^{2-}, serum organic phosphate increased greatly (104%), and there was a parallel, but even greater increase in serum total cholesterol (155.2%). The estimated serum cholesterol : phospholipid ratio remained essentially the same as in the mock-operated controls (0.362 as compared with 0.352, respectively).

1198. Stanley, J.G. 1969. Seasonal changes in the electrolyte metabolism in the alewife, Alosa pseudoharengus, in Lake Michigan. Internat. Assoc. Great Lakes Res., Proc. 12th Conf. Great Lakes Res. 1969: 91-97.

Adult alewives (fishes) from Lake Michigan were collected during the summer of 1968. Sodium, potassium and calcium levels were determined in serum and tissue samples. Transient hyponatremia was observed in June and July, together with increased sodium content of tissues; suggesting a temporary shift in water or sodium between body fluid compartments. There were no significant changes in potassium levels. Changes in calcium levels during the breeding season suggest deposition of calcium in bone but not in scales. Hypercalcemia was not found in females during the breeding season. The shifts between body fluid compartments may be a contributing factor in the mass mortalities observed in the alewife.

1199. Stanley, J.G., and P.J. Colby. 1971. Effects of temperature on electrolyte balance and osmoregulation in the alewife (Alosa pseudoharengus) in fresh and sea water. Trans. Amer. Fish. Soc. 100(4):624-638.

A study of the effects of temperature and salinity on ionoregulation in the herring-like alewife revealed that concentrations of Na, K and Ca in plasma and muscle were similar in fish adapted to fresh water and those adapted to sea water. The non-stressed alewife is apparently an excellent ionoregulator in both environments. Acute exposure to cold caused a shift in plasma concentrations of sodium and calcium toward environmental concentrations, i.e. these ions decreased in fresh water and increased in sea water. An ionoregulatory failure due to cold is suggested. High temperatures had little effect on plasma electrolyte levels in fresh water whereas in sea water the concentrations of Na, K, and Ca were elevated. Mortalities of alewife in the Great Lakes may be caused by osmoregulatory failure induced by acute exposure to cold, but are probably not induced by exposure to elevated temperatures. Fish thermally acclimated in the laboratory or in Lake Michigan had essentially normal concentrations of blood electrolytes. In muscle, Na was reduced during exposure to acute cold in both fresh water and sea water. The effect of warm water on ion levels in muscle was, in general, opposite that of cold. These data suggested shifts of ions or water between cellular and extracellular fluids of muscle. Such shifts might affect the function of excitable tissue. Muscle tremors and loss of equilibrium observed in dying alewives during summer mortalities might be brought about when a sudden temperature drop (e.g., as a result of upwellings which are common occurrences in the Great Lakes) induces disturbances in cellular or extracellular concentrations of ions. In the laboratory, alewife mortalities caused by increasing or decreasing temperatures were about equal in fresh water and sea water. These findings suggest that salinity does not modify the capacity of alewives to tolerate acute temperature stress.

1200. Stickney, R.R., and B.A. Simco. 1971. Salinity tolerance of catfish hybrids. Trans. Amer. Fish. Soc. 100(4):790-792.

Determination of salinity tolerance in freshwater catfish is of interest since commercial production of these fish in brackish water may be attempted in the future. The salinity tolerance of several hybrid catfishes was examined at the Fish Farming Experimental Station during the summer of 1969. Fingerlings of the 1969 year class were used and included 3/4 blue: 1/4 channel, 3/4 channel: 1/4 blue, and 1/2 channel: 1/2 blue catfish hybrids. The medium used in these experiments was artificial seawater. Hybrids investigated in this study were able to tolerate salinities between 14 and 15^{o}/oo for periods of 96 hours. They showed a similar salinity tolerance to that demonstrated by non-hybrid channel catfish fingerlings. It is suggested that these findings be verified under natural seawater conditions.

1201. Stoddart, D.R., G.W. Bryan, and P.E. Gibbs. 1973. Inland mangroves and water chemistry, Barbuda, West Indies. Jour. Nat. Hist. 7:33-46.

Mangrove vegetation, comprising not only *Laguncularia* and *Conocarpus*, but also a closed woodland of *Rhizophora*, is found in inland situations in Barbuda, West Indies, having no connection with the sea and associated with geological and geomorphic features of either late Pleistocene or possibly earlier Holocene age. These mangroves are associated with brackish water. Analyses show lowered concentrations of sodium, potassium and magnesium and higher concentrations of calcium and strontium compared with sea water having the same chloride content, the higher calcium and strontium concentrations probably resulting from diagenetic changes in the limestone. The inland mangroves are either relict from the period of the lithified beach ridges, or they have more recently colonized the platin area. More data are required on their geological setting before this can be resolved.

1202. Strohal, P., and T. Pinter. 1973. Thorium in water and algae from the Adriatic Sea. Limnology and Oceanography 18(2): 250-253.

Thorium concentrations were determined in filtered and unfiltered seawater as well as in marine algae. In filtered seawater, values were 8×10^{-13} g Th/l and lower; for unfiltered seawater samples, values about 1000x higher were obtained. Thorium concentrations in marine algae are in the range 10^{-6} to 10^{-8} g Th/g ash wt.

1203. Surber, E.W., and O.L. Meehean. 1931. Lethal concentrations of arsenic for certain aquatic organisms. Trans. Amer. Fish. Soc. 61:225-239.

Fish culturists who might wish to use this chemical in the control of bothersome submerged vegetation in fish ponds may receive some encouragement from the fact that a treatment of 2.0 mg/l of arsenious oxide equivalent in sodium arsenite "Weed Killer" solution will not cause important fish food organisms to die on exposure to the chemical. Chironomid larvae, mayfly nymphs and fresh-water shrimp, *Hyalella*, appeared to be most sensitive to the treatments with relatively high mortality rates following exposure to 2.5 - 4.0 mg/l of As_2O_3. Damselfly and dragonfly nymphs, *Asellus*, and water mites survived concentrations of 10.5 - 21 mg/l of As_2O_3. The protozoa, *Colpidium*, *Paramecium*, and *Stylonichia* survived and multiplied when exposed to 3.5 mg/l As_2O_3. The green alga *Spirogyra* was affected by a treatment of 1.75 mg/l As_2O_3, but was not killed by it. The quantity of arsenic is reduced rapidly in aquaria when samples are taken at some distance from the bottom. The amount of reduction is about 75% in five days with concentrations of 3.0 - 7.9 mg/l, but is more rapid when smaller concentrations are used. Stirring water in the aquaria before taking a sample increased the amounts of arsenic in samples indicating that the arsenic is percipitated out by elements present in the water.

1204. Swinehart, J.H., W.R. Biggs, D.J. Halko, and N.C. Schroeder. 1974. The vanadium and selected metal contents of some ascidians. Biol. Bull. 146:302-312.

Vanadium and other selected metal contents of primarily California ascidians have been determined. The species *Ascidia ceratodes* and *Perophora annectens* have large vanadium contents as has been predicted for members of the families Ascidiidae and Perophoridae from the order Phlebobranchia. Several species in the order Aplousobranchia have large vanadium contents: the vanadium being present as vanadium (IV) whereas it is vanadium (III) that is found in the order Phlebobranchia *Molgula manhattensis*, a species from the order Stolidobranchia, shows a large iron content: the metal being localized in the fluid from the heart.

Three dominant fractions were chromatographed from the cells contained in the fluid of *Ascidia ceratodes*. The roles of the compounds present in these fractions are discussed. The spectra of these fractions are correlated with the spectrum of the cells.

1205. Sykora, J.L., E.J. Smith, and M. Synak. 1972. Effect of lime neutralized iron hydroxide suspensions on juvenile brook trout (*Salvelinus fontinalis*, Mitchill). Water Research 6(8):935-950.

The experimental dosing apparatus was a modified proportional diluter equipped with a neutralization device and with a series of detention and oxygenation tanks. Ferric hydroxide was obtained by neutralization of ferrous sulfate using calcium hydroxide. After neutralization, oxygenation, and detention, suspended iron was released automatically at regular intervals into the test aquaria. Four concentrations of iron were maintained, each containing 10 young brook trout (3 months old). The data on length of brook trout revealed a definite trend toward smaller size with increasing concentration of suspended ferric hydroxide, with the largest trout in 6 mg Fe/l and in the control. The average weight of brook trout was much lower in high iron concentrations than in the control and 6 mg Fe/l. The final mean weight of fish in 50 mg Fe/l represented only 16% of the control, with gradually increasing percentage proportions occurring in lower iron concentrations. The final mean weights of the fish in 6 mg Fe/l and in the control were almost identical. The average growth rate computed for five different size groups of fish revealed a sudden decline in growth of brook trout exposed to 12, 25, and 50 mg Fe/l. The growth rate of brook trout in 6 mg Fe/l and in the control shows only a leveling trend as of the thirty-fifth week. It is assumed that impaired visibility due to high turbidity prevented the fish from feeding which in turn resulted in slow growth in high iron concentrations—12, 25 and 50 mg Fe/l.

1206. Takevchi, T. 1972. Distribution of mercury in the environment of Minamata Bay and the inland Ariake Sea. In Hartung, R. and B.D. Dinman (eds.). Environmental Mercury Contamination. Ann Arbor Science Publishers, Inc.: 79-81.

In 1959 extremely large concentrations of Hg were contained in the sediment of Minamata Bay, Japan. Near the drainage channel that leads into the bay from several chemical plants, a maximum concentration of 2,010 mg/kg (wet weight) Hg was found in sediment. Concentrations of Hg in the sediment dropped sharply as a function of the distance from the effluence point of the factory drainage channel into Minamata Bay. As the distance from the channel entrance increased, the Hg concentrations in the sediments continued to decrease rapidly until the sediment directly outside Minamata Bay contained only 0.4 to 3.4 mg/kg Hg. The concentration of Hg in shellfish, fish, and other seafoods was also found to be a function of distance from the point of effluence.

1207. Telitchenko, M.M., G.V. Tsytsarin, and Y.L. Shirokova. 1970. Trace elements and algal "bloom." Hydrobiological Jour. 6(6):1-6.

Aphanizomenon flos-aquae and Microcystis aeruginosa (Cyanophyceae) concentrate 18 trace elements from water, one of which is copper. When copper stocks are exhausted the "bloom" of Cyanophyceae in the body of water ceases. Repeated "blooms" are noted only when the water is enriched with copper by the death of the previous generation of algae. It is therefore concluded that the "bloom" should not be combatted by treatment with copper sulfate.

1208. Telitchenko, M.M., G.V. Tsytsarin, and Y.L. Shirokova. 1970. Trace elements and water bloom. Hydrobiological Jour. 6(6): 7-12.

By emission spectral analysis of material and phytoplankton of the Mozhaisk reservoir the following 24 trace elements were determined: Ta, Nb, Au, Hg, W, Sb, Zn, Zr, Ag, Co, Sn, V, Be, Bi, As, Mn, Ti, Ba, Cu, Sr, Mo, Pb, Cr, and Ni. Of these, Ta, Nb, Au, Hg, W, and

Sb were found neither in algae, nor in water. Zn and Zr are accumulated in microgram amounts by drying the algae. Traces (0.001 mg/kg) of Ag, Co, Sn, V, Be, Bi, and As are observed in algae during bloom. The other elements were found in both water and algae. *Aphanizomenon flos-aquae* and *Microcystis aeruginosa* when blooming in the reservoir, leave traces of Sr, Cr, and Ni. The repeated blooms of *Cyanophyta* in the reservoirs are observed only when water is enriched with Cu of the previous dying algae generation.

1209. Templeton, W.L. 1970. Disposal of liquid wastes into coastal waters. Chemical Engin. Prog. 66(2):45-50.

The danger to man from disposal of radioactive wastes is now probably better understood than any other industrial risk. Aside from dose limits set by the International Commission on Radiological Protection, the permissible discharge rates depend on the concept of critical populations, as well as degree of dilution, dispersion, and reconcentration of radionuclides. The external and internal exposure of both physical and biological nature are additional factors delineating the disposal of radioactive wastes. The situation is illustrated as it now exists at the discharge points of English coastal waters. Examples include ruthenium-106, strontium-90, zinc-65, cobalt-60, and critical material, such as *Porphyra umbilicalis*, an edible seaweed, fish, oysters, and either the total body of man or his lower large intestine. The approach of the United Kingdom toward disposal of radioactive wastes is considered with reference to disposal of other pollutant materials. A similarity of chlorinated hydrocarbons with radionuclides is pointed out.

1210. Templeton, W.L., J.M. Dean, D.G. Watson, and L.A. Rancitelli. 1969. Freshwater ecological studies in Panama and Colombia. BioScience 19(9):804-808.

Studies were made to acquire data for evaluation and prediction of potential radiation dose to indigenous populations in the region of proposed nuclear excavations. Collections were made at 19 stations in Panama and 15 stations in Colombia; chemical and activation analyses were made of water, suspended solids, and tissues of fish and invertebrates. Low concentrations of elements suggest high capacity for retention and cycling in terrestrial-soil ecosystem. Interflow predominates over sheet run-off. Water samples show relatively high concentrations of sodium, magnesium, cobalt, chromium, and cesium and low concentrations of potassium, iron, and antimony compared with mean values for all rivers. Concentration factors of stable elements vary with tissue analyzed, being highest for phosphorus, mercury, potassium, and copper. Contributions of direct fallout to freshwater ecosystems are likely to be small owing to the vegetation canopy. Occurrence of peak concentrations will depend on rate of movement through terrestrial and groundwater systems; these should dampen the peaking effect.

1211. Tennant, D.A., and W.D. Forster. 1969. Seasonal variation and distribution of 65-Zn, 54-Mn, and 51-Cr in tissues of the crab *Cancer magister* Dana. Health Physics 18:649-659.

Crabs from the Columbia River estuary were analyzed for stable and radioactive Cr, Zn, and Mn. Chromium-51 and zinc-65 accounted for nearly all the gamma radioactivity in the tissues, the Zn-65 being mainly concentrated in soft tissues and the Cr-51 in the hard tissues. Manganese-54 concentrations were highest in the setae and calcareous exoskeleton, presumably because of surface adsorbed Mn-54O$_2$. Specific activities and radioactivities fluctuated throughout the year in much the same manner, with maximum radioactivities seemingly related to river discharge and peak specific activities due to metabolic changes in the crab. Specific activities suggest that surface adsorbed radionuclides are turned over faster than internally adsorbed radionuclides.

1212. Thorp, V.J., and P.S. Lake. 1974. Toxicity bioassays of cadmium on selected freshwater invertebrates and the interaction of cadmium and zinc on the freshwater shrimp *Paratya tasmaniensis* Riek. Austral. Jour. Mar. Freshwat. Res. 25:97-104.

In acute toxicity bioassays with cadmium sulphate at 15°C in soft water (total hardness 10 mg/l as calcium carbonate), the concentrations fatal to 50% of the test animals were determined for five freshwater invertebrate species. The 96 hr median lethal concentration (LC-50) of cadmium was 0.04 mg/l for the amphipod *Austrochiltonia subtenuis* Sayce, 0.06 mg/l for the shrimp *Paratya tasmaniensis* Riek, 0.84 mg/l for the ephemeropteran nymph *Atalophlebia australis* Walker, 250 mg/l for the zygopteran nymph *Ischnura heterosticta* (Burmeister) and well over 2000 mg/l for a trichopteran larva of the Leptoceridae. The bioassays on *Paratya* indicated that there may be seasonal differences in sensitivity to cadmium. The 96 hr LC-50 for zinc for *Paratya* was 1.21 mg/l. Zinc and cadmium appeared to interact less than additively at concentrations below 1 toxic unit. Above this concentration, their interaction was strictly additive.

1213. Thurberg, F.P., M.A. Dawson, and R.S. Collier. 1973. Effects of copper and cadmium on osmoregulation and oxygen consumption in two species of estuarine crabs. Marine Biology 23:171-175.

Green crabs (*Carcinus maenas*) and rock crabs (*Cancer irroratus*) were exposed to various concentrations of copper as cupric chloride

($CuCl_2 \cdot 2H_2O$) and cadmium as cadmium chloride ($CdCl_2 \cdot 2\ 1/2\ H_2O$) for 48 h. The exposures were conducted at 5 different salinities. At the end of each exposure period, tests of blood-serum osmolality and gill-tissue oxygen consumption were performed. Copper-exposed crabs exhibited loss of osmoregulatory function with increasing copper concentration until normally hyperosmotic serum became isosmotic with the surrounding medium. Cadmium elevated green-crab serum above its normal hyperosmotic state. Copper had no effect on gill-tissue oxygen consumption; however, cadmium reduced the rate of oxygen consumption in both species tested.

1214. Tillander, M., J.K. Miettinen, and I. Koivisto. 1972. Excretion rate of methyl mercury in the seal (Pusa hispida). In Ruivo, M. (ed.). Marine Pollution and Sea Life. Fishing Trading News (books) Ltd., London: 303-305.

The excretion rate of methylmercury in the ringed seal (Pusa hispida saimensis Nordg.) was determined using Hg-203 labelled methylmercury as a protein bound preparation with peroral administration, and the whole body counting technique. During the first month methylmercury was translocated from stomach into fatty tissue on the surface of the animal. Between 100 to 153 days, however, a straight line was obtained on a semi-logarithmic plot giving for the "slow" component of excretion a half-time of 500 days. About 45% of the dose given follows this excretion rate. Between 30 and 100 days a "fast component" is evident, having a half-time of the order of 20 days; this value is approximate only because of the masking effect of the geometry change. This investigation was conducted because toxic levels of mercury were recently measured in the small relic population of ringed seal in Lake Saimaa, a species which is on an endangered list.

1215. Timms, A.M., and H. Kleerekoper. 1972. Locomotor response of goldfish, channel catfish, and largemouth bass to a 'copper-polluted' mass of water in an open field. Water Res. Research 8(6):1574-1580.

The locomotor response of goldfish, largemouth bass, and channel catfish to 'copper-polluted' water at a maximum concentration of 50 μg/l Cu^{++} in an open field, free choice situation was monitored. The largemouth bass were unaffected, but goldfish and channel catfish tended to orient toward the source of the ion. The degree of this orientation was less, however, than that found in shallower gradients of the same copper concentration. When goldfish were exposed to the copper ion in a uniform field so that neither avoidance of nor attraction to the polluted mass was possible, no change in orientation was observed. It is concluded that the slope of the copper gradient between 'clean' and 'polluted' water rather than the eventual highest concentration of the ion (50 μg/l) affected orientation and locomotor behavior of the catfish and the goldfish.

1216. Timoshchuk, V.I. 1970. Sr in water of the Caspian and Azov Seas. In Marine Radioecology: 185-196. Available from Nat. Tech. Inf. Ser., Springfield, Va., as Part of AEC-tr-7299.

Leaching of shoreline rocks gives high Sr concentrations (21-25 mg/l) in certain regions of the Caspian Sea relative to regions diluted by river discharges (0.5-2.5 mg/l). Sr in the Sea of Azov (3.1-6.1 mg/l) is affected by exchange with the Sivash Bay where evaporation gives high Sr concentrations (26 mg/l). Concentration factors for Sr-90 measured in 1966 were higher for semimigratory fish (roach, 40; carp, 33) than for migratory fish (kutum, 2.5).

1217. Ting, R.Y. 1971. Distribution of Zn, Fe, Mn, and Sr in marine fishes of different feeding habits. In Radionuclides in Ecosystems, Proc. Third Nat. Symp. Radioecol. 2:709-720.

The levels of Zn, Fe, Mn, and Sr, concentrations in muscle, viscera, skin, scales, and bone of seven species of fish composed of four different feeding habits were determined by atomic absorption spectrophotometry. Samples were taken from the Gulf of Panama and Puerto Rican waters and included herbivores and carnivores of three distinctly different feeding habits including: the herbivorous mullet (Mugil curema); planktonic-feeding Pacific thread herring (Opisthonema libertate) and Atlantic thread herring (Opisthonema oglinum); benthic carnivorous sea trout (Cynoscion reticulatus) and sand perch (Diplectrum euryplectrum); and the pelagic carnivorous yellowfin tuna (Thunnus albacares) and skipjack tuna (Euthynnus pelamis). There were no significant differences in levels of Zn, Fe, Mn, and Sr concentrations in muscle, viscera, skin, scales, and bone in the seven species of fish composed of four different feeding habits, except that levels of Fe in viscera were significantly different. Viscera of mullets contained a significantly higher amount of Fe than the carnivores. This probably was due to the sediments ingested with diatoms, detritus and algal matter when mullets are feeding from the bottom. The levels of the elemental concentrations in all body parts often varied to significant degrees between species within the same feeding habits.

1218. Tong, S.C., W.H. Gutenmann, D.J. Lisk, G.E. Burdick, and E.J. Harris. 1972. Trace metals in New York State fish. N.Y. Fish Game Jour. 19(2):123-131.

An analytical survey was conducted of the concentrations of eight metals in fish from 11 New York State waters. Analysis of barium, cadmium, cobalt, nickel, silver, tin, vanadium and zinc in fish was performed by spark source mass spectrometry following dry ashing in samples. Barium, cadmium and silver were present in the range of 0.1 mg/kg. Tin and zinc were usually found at relatively higher levels of 0.5 to several mg/kg. Cobalt, nickel and vanadium were intermediate in concentration being most often less than 1 mg/kg.

1219. Tong, S.S.C., W.D. Youngs, W.H. Gutenmann, and D.J. Lisk. 1974. Trace metals in Lake Cayuga lake trout (Salvelinus namaycush) in relation to age. Jour. Fish. Res. Bd. Canada 31:238-239.

Chromium concentration increased, and molybdenum and tin concentrations decreased in Lake Cayuga lake trout (Salvelinus namaycush) from age 1 to 12 yr. The concentration of the rare element rhodium ranged from about 100 to 200 μg/l. The concentrations of 33 other trace metals in the fish are reported.

1220. Torma, A.E., and F. Habashi. 1972. Oxidation of copper (II) selenide by Thiobacillus ferrooxidans. Canad. Jour. Microbio. 18(11):1780-1781.

Thiobacillus ferrooxidans is an organism which tolerates high metal ion concentrations and can oxidize metallic sulfides, low valency inorganic sulfur compounds, ferrous ion and some other compounds. The action of T. ferrooxidans upon copper selenide was investigated. The organism had a catalytic effect on the oxidation process. During leaching for sulfide, acid had to be added to maintain the optimum pH of 2.3. In spite of the high toxicity of selenium, the bacteria grew and multiplied. In this process copper goes into solution and elemental selenium is deposited.

1221. Townsley, S.J. 1963. The effect of environmental ions on the concentration of radiocalcium and radiostrontium by euryhaline teleosts. In Schultz, V., and A.W. Klement, Jr. (eds.). Radioecology. Reinhold Publ. Corp., New York: 193-199.

Euryhaline fish (Tilapia mossambica) exposed for two weeks to fresh water, fresh water plus added calcium, and sea water containing equal concentrations of strontium-89 show concentrations of the nuclide in their tissues in inverse order to the calcium plus strontium, but not directly related to absolute amounts of the ions. Although 50 times more stable calcium is present in salt water, the amount of strontium-89 retained in tissues was not 50 times greater in salt-water fish. It is assumed that the Sr^{++} in the environments cannot account for the differences. Exposure of T. mossambica to fresh waters and sea waters with varying concentrations of Ca^{++} and Sr^{++}, and ratios of these ions to one another, shows that radiocalcium and radiostrontium accumulation and retention are controlled by several factors including the total divalent ions present, as well as other salts in the environment.

The effects of increased concentrations of Sr^{++} in the environment have little effect upon the total radioactive calcium plus strontium absorbed, nor upon their ratio. It would appear, therefore, that for decontamination of aquatic environments, addition of calcium salts and other divalent ions could be more effective against absorption of radiocalcium and radiostrontium than addition of Sr^{++} alone. It does not appear that release of radiocalcium or radiostrontium into marine or brackish environments would result in as much absorption and retention of radioactive strontium or calcium as in fresh water environments. This is particularly important to the species which show migratory or osmotic regulation habits. Thus under differing environmental conditions, the same species of fish may show varying degrees of accumulation and retention of radiocalcium and radiostrontium.

1222. Triquet, C. 1973. Study of the contamination of *Arenicola marina* L. by cobalt-60. Comptes Rend. de l'Acad. Sci. 276 (Series D, No. 4):645-648.

Populations of the marine polychaete *Arenicola marina* were contaminated with cobalt-60 from wastes of the nuclear power industry. These vectors were suggested: water, substrate, sediments, and organic material in the sediments (*Arenicola* is a suspension feeder). Such organisms concentrate cobalt-60 to a high degree in their blood. The method of contamination was studied experimentally in water contaminated with chloride of cobalt-60. Results of the contaminant concentration studies indicated water passing over the sediments as the vector. The concentration of radioactivity at the digestive tube levels in the worms indicated that contaminants are concentrated in organic material in sediments and then ingested.

1223. Tsuchiya, K. 1969. Epidemic of mercury poisoning in the Agano River area: An introductory review. Keio Jour. Medicine 18(4):213-227.

Fish were contaminated by inorganic mercury and by methylmercury, but it was not clear how and when the river was polluted. The source of mercury was either industrial or pesticidal.

1224. Turekian, K.K., A. Katz, and L. Chan. 1973. Trace element trapping in pteropod tests. Limnology and Oceanography 18(2):240-249.

Pteropod tests from the Gulf of Aqaba and the South Atlantic Ocean and "bulk" (soft tissue) plankton samples from Long Island Sound were analyzed by instrumental neutron activation analysis (INAA) for 11 trace metals (Fe, Ce, La, Sm, Eu, Th, Sc, Cr, Co, Sb, Se) to study the trapping and transport mechanisms for these metals in the oceans and the capability of pteropods to modify the composition of seawater during this process. The internal correlations among these metals strongly suggest that a finely particulate (<0.2 μ) authigenic iron-rich phase (hydrated oxide or phosphate) is trapped by both the soft and hard tissues of plankton and that this phase is the major carrier of several of the trace metals. Assuming that the iron-rich floc-trapping mechanism is applicable to all pelagic calcareous tests, then the downward flux of iron and associated trace elements carried by these tests can be assessed. This assumption leads to the conclusion that the iron and the associated trace elements have residence times in the deep water of the same order of magnitude as that of the deep water itself.

1225. Turner, J.L., and T.C. Farley. 1971. Effects of temperature, salinity, and dissolved oxygen on the survival of striped bass eggs and larvae. California Fish and Game 57(4):268-273.

Laboratory experiments were conducted on effects of salinity, temperature, and dissolved oxygen on survival of artificially spawned striped bass (Morone saxatilis) eggs and larvae. Egg survival in salinities greater than about 1,000 mg/l total dissolved solids, especially at higher temperatures, are greatly reduced if eggs are not water hardened in fresh water. Moderate reductions in dissolved oxygen (to 4 or 5 mg/l) adversely affect the percent hatch of eggs and have a detrimental effect on larval survival.

1226. Uchida, M., K. Hirakawa, and T. Inoue. 1961. Biochemical studies on Minamata disease III. Relationships between the causal agent of the disease and the mercury compound in the shellfish with reference to their chemical behaviors. Kumamoto Medical Jour. 14(4):171-179.

The mercury compound in the contaminated shellfish, Hormomya mutabilis was consistently recovered in those fractions in which the causal agent of Minamata disease was present.

1227. Ui, J. 1972. A few coastal pollution problems in Japan. In The Changing Chemistry of the Oceans. Proc. 20th Nobel Symp., Stockholm, Sweden. John Wiley and Sons, Inc., Wiley Interscience Div., New York: 171-176.

Tokyo Bay receives about 200 kg Hg/day from various sources. The distribution of Hg among biomass and sediment is complicated by the existence of heavy organic pollution in the bay. Recently a few species of pelagic fish such as tuna, swordfish, and certain sharks, were found to have high Hg levels. However, it is not clear whether the coastal pollution by Hg in Japan has any relation to this phenomenon. A possible explanation is given for the wide difference between accumulation of Hg in fish and quantity of Hg in the same district of the sea. The accumulation of Cd and PCBs in coastal fish of Japan is also discussed.

1228. Umminger, B.L. 1969. Physiological studies on supercooled killifish (Fundulus heteroclitus). I. Serum inorganic constituents in relation to osmotic and ionic regulation at subzero temperatures. Jour. Exper. Zool. 172(3):283-302.

Physiochemical properties (serum osmolality and blood pH), serum inorganic ions (sodium, potassium, calcium, magnesium, chloride, phosphate and bicarbonate) and tissue water were studied in parallel groups of adult male killifish acclimated to various temperatures (30°C, 20°C, 10°C, 4°C, 2°C, -1°C and -1.5°C) in salt water under otherwise constant laboratory conditions. When the acclimation temperature was lowered from 20° to -1.5°C, serum osmolality increased by 20%. This increase was not indicative of osmoregulatory failure, however, since the proportion of total serum osmolality accounted for by inorganic electrolytes dropped from 98% at 20°C to 93% at -1.5°C. Serum electrolytes such as sodium, chloride, calcium, magnesium and bicarbonate increased in the subzero cold by 12%, 17%, 30%, 33% and 11% respectively whereas serum potassium and inorganic phosphate levels were unchanged. Blood pH was significantly higher at 10°C than at any other temperature. The water content of liver, testes and muscle decreased by 8% in the subzero cold. These changes in serum electrolytes and tissue water did not indicate osmoregulatory failure; the new levels once established were maintained as long as the fish were alive. Although osmotic and ionic regulation were not as effective in the cold, they were by no means so poor as to cause death by osmotic imbalance.

1229. Umminger, B.L. 1971. Osmoregulatory overcompensation in the goldfish, Carassius auratus, at temperatures near freezing. Copeia 1971(4):686-691.

The serum chemistry of goldfish was examined at 20°, 10°, and 0.15°C. Acclimation to temperatures near freezing was characterized by a decrease in serum electrolytes (sodium, chloride and potassium), an increase in serum osmolality, and an increase in serum glucose. An increase in the serum osmolality of a freshwater fish in the cold despite reductions in the concentrations of serum electrolytes has been termed osmoregulatory "overcompensation." The goldfish is the first fish in which this pattern of osmoregulation has been reported. The increase in serum osmolality in the cold was not the result of an increase in serum glucose (which was osmotically insignificant), but rather to a buildup of yet unidentified, probably organic, constituents of the serum.

1230. Umminger, B.L. 1973. Death induced by injection stress in cold-acclimated goldfish, Carassius auratus. Comp. Biochem. Physiol. 45:883-887.

Goldfish responded to injections of either saline or prolactin with a hyperglycemia and a decline in serum sodium and chloride concentrations. These stress-induced responses were most pronounced in fish acclimated to 1°C and less apparent in fish acclimated to 20°C. No deaths were observed in uninjected fish at 20° or 1°C or in injected fish at 20°C. At 1°C, however, eight of eighteen injected fish died within 10 days and the survivors were in poor physiological condition. The stressful effects of injection procedures become progressively more pronounced in goldfish as the acclimation temperature is lowered and, at temperatures near freezing, injection stress is so severe as to cause death.

1231. Umminger, B.L., and J.B. Mahoney. 1972. Seasonal changes in the serum chemistry of the winter flounder, Pseudopleuronectes americanus. Trans. Amer. Fish. Soc. 101(4):746-748.

The winter flounder shows seasonal cycles in the osmotic pressure of its serum. The serum freezing point varied from an average of -1.15°C during winter to -0.63°C in summer. The increased osmotic pressure may function in protecting fish against freezing in cold, shallow waters. Recent studies on laboratory-acclimated winter flounder showed that temperatures ranging from 15°C to -1°C had no effect on serum osmolality. Therefore, seasonal change in the serum osmolality of winter flounder in the natural environment is probably not temperature controlled.

1232. Ünlü, M.Y., M. Heyraud, and S. Keckes. 1972. Mercury as a hydrospheric pollutant. I. Accumulation and excretion of $^{203}HgCl_2$ in Tapes decussatus L. In Ruivo, M. (ed.). Marine Pollution and Sea Life. Fishing Trading News (books) Ltd., London: 292-295.

Some aspects of mercury's metabolism in the clam, Tapes decussatus L., related to the potential hazard from mercury pollution of marine environment are described. Mercury as Hg-203 was used in chloride form. Mercury is rapidly accumulated by Tapes from sea water and within 1 day the animals contain 10 times more mercury per unit weight than their environment. During longer exposure the accumulation of mercury is considerably slowed down. The visceral organs contain more than half of the mercury accumulated during 14 days, while the muscles contain less than 2% of the total accumulated mercury.

The loss rate of the accumulated mercury does not depend on the duration of the animal's exposure to it, but is strongly dependent on the method of its entry. The retention of the accumulated mercury is highest after it was introduced into Tapes by injection into foot muscle; only about 25% of the injected mercury is lost within 2 months, mostly in the first 6 days. The retention of mercury accumulated from sea water or through the food chain is not too strong and has an overall biological half-time of about 10 and 5 days respectively.

1233. Uthe, J.F., F.M. Atton, and L.M. Royer. 1973. Uptake of mercury by caged rainbow trout (Salmo gairdneri) in the South Saskatchewan River. Jour. Fish. Res. Bd. Canada 30(5):643-650.

Trout were held in cages in the South Saskatchewan River to assess mercury uptake following curtailment of mercury discharges to the river. Six fish were randomly taken from the cages at 2-week intervals and pooled homogenate samples prepared of livers, kidneys, and headless, dressed carcasses. The total mercury content of samples was determined by flameless atomic absorption spectroscopy. There was a rapid uptake of mercury by the fish during the first warm summer period (1970) with much less uptake during the rest of the year. A second summer experiment (1971) produced no significantly different results suggesting that a long-term contamination exists within this river system. Analyses showed that the bulk of mercury present in the fish carcasses was present as methylmercury. It was concluded that caged fish are good monitors of mercury pollution. The studies also showed that the cessation of mercury discharge into a river does not lead to elimination of mercury uptake in fish.

1234. Van As, D., H.O. Fourie, and C.M. Vleggaar. 1973. Accumulation of certain trace elements in the marine organisms from the sea around the Cape of Good Hope. In Radioactive Contamination of the Marine Environment. Int. Atom. Ener. Agen., Vienna, Austria: 615-624.

An investigation of the recipient capacity of the sea for radioactive effluent from a site on the west coast of South Africa, 25 km north of Cape Town, necessitated the determination of concentration factors for those nuclides which would probably be present in the effluent of the proposed nuclear installations. Stable element analyses were done for these corrosion elements which are known to have high accumulation factors and which have induced radioactive isotopes of long half-lives, e.g. Cr, Fe, Zn, Co, Mn and Sb, as well as for the stable counterparts of the fission products Sr-90 and Cs-137. Various methods of sample preparation, e.g. freeze drying, dry and wet ashing, and of sample analyses, e.g. atomic absorption and neutron activation, were used in parallel and the results compared. The marine organisms which are either regularly consumed or which may have future economic importance were investigated. These species included algae (*Poryphyra capensis*, *Ecklonia maxima*, *Ulva* spp., *Suhria vitatte*), molluscs (*Haliotis midae*, *Donax serra*, *Mytilus meridonalis*) and crustacea (*Jasus lalandii*), as well as various line and pelagic fishes of commercial importance. Analyses were normally performed on the edible parts of the species only. With regard to coastal and off-shore waters, measurements of the soluble and particulate fractions of these elements were made and different techniques of sample storage and sample preparation, e.g. deep freezing and freeze-drying, were compared.

1235. Van Coillie, R., and A. Rousseau. 1974. Composition minérale des écailles du *Catostomus commersoni* issu de deux milieux différents: étude par microscopie électronique analytique. Jour. Fish. Res. Bd. Canada 31:63-66.

The elemental content of scales from the teleost *Catostomus commersoni* was studied. Fish were collected from a healthy environment (the Manicouagan River) and an environment polluted by several substances, including various heavy metals (Riviére des Prairies, near Montreal). X-ray microspectrometry was combined with electron microprobe scanning techniques, with subsequent microdensitometric scanning. Scales contained, in addition to the highly predominant calcium, the following: Na, Mg, Al, K, Fe, Cu, Zn, and Ba, as well as some Cr, Mn, Co, Ni, Sr, Ag, Cd, Cs, Hg, and Pb. All metals were between the circuli in the osteoid structures. The latter category of metals, widely known for their toxicity, were more abundant in scales of samples from polluted waters, whereas the reverse was true for the other metals, with the exception of Al and Ba, which were found in equal quantities in both samples. If differences in metal content of scales taken from fish of the two different environments is related to abundance of toxic metals in polluted waters and that the possibility exists that excess metal from the water can replace calcium in the scales, then it is inferred that mineral content of scales is related at least in part to that of the surrounding aquatic environment.

1236. Van Weers, A.W. 1973. Uptake and loss of ^{65}Zn and ^{60}Co by the mussel *Mytilus edulis* L. *In* Radioactive Contamination of the

Marine Environment. Int. Atom. Ener. Agen., Vienna, Austria: 853-401.

The uptake of Zn-65 and Co-60 directly from seawater by mussels and subsequent loss of radionuclides in non-radioactive seawater were studied with animals kept unfed during the experiments. Concentration factors measured for radionuclides during periods up to 60 days are much lower than values for stable elements, which range from 3,000 to 11,000 for zinc and from 1,200 to 4,500 for cobalt in soft parts. The pattern of loss is described by loss from two relatively short-lived components and one long-lived component, the relative importance of the latter increasing with the length of the preceding uptake period. The biological half-life of the long-lived component ranges from 48-60 days for Zn-65 and from 57-72 days for Co-60. As shown by autoradiography, Zn-65 is accumulated to a high extent in the kidney and Co-60 in both kidney and digestive gland. Author concludes that, as far as uptake of Zn-65 and Co-60 directly from seawater is concerned, both the relatively slow accumulation and subsequent loss will reduce risk of contamination of mussels following incidental releases of these radionuclides in coastal waters.

1237. Van Winkle, W., Jr. 1970. Effect of environmental factors on byssal thread formation. Marine Biology 7:143-148.

The effects of various factors on byssal thread formation were examined in the laboratory using the mussels Modiolus demissus and Mytilus edulis. With M. demissus thread formation (threads/mussel/h) and proportion of mussels forming threads decreased with increasing size; prior exposure to air enhanced subsequent thread formation; mechanical agitation reduced thread formation. In addition, low salinity-acclimated mussels adapted more rapidly to 32°/oo than high salinity-acclimated mussels did to 16°/oo; threads were not formed in the absence of calcium and/or magnesium; and there was no reduction in thread formation at temperatures as high as 27° to 28°C. M. edulis died and thread formation approached zero at temperatures exceeding 26°C.

1238. Vaskovsky, V.E., O.D. Korotchenko, L.P. Kosheleva, and V.S. Levin. 1972. Arsenic in the lipid extracts of marine invertebrates. Comp. Biochem. Physiol. 41B(4):777-784.

The quantitative contents of arsenic in lipid extracts of 27 species of marine invertebrates, related to various systematic groups, were determined. Arsenic was found in lipids of representatives from all phyla. Annelids, molluscs and asteroids (Echinodermata) had the highest arsenic contents whereas Spongia (Porifera) had the lowest.

Lipids of animals of the same species with different habitats were found to have different arsenic contents. Thin-layer chromatography was used to compare arsenic-containing substances obtained from various organisms. Animals from different groups were shown to have different arsenic-containing compounds. The main portions of arsenic-containing substances saponify.

1239. Vaughan, B.E., and J.A. Strand. 1970. Biological implications of a marine release of Sr-90. Health Physics 18:25-41.

For a situation represented by instantaneous release of strontium-90-oxide in the ocean, a model of biotic radiocontamination has been devised based more realistically on known characteristics of coastal marine organisms. In this contamination model, radioactivity concentration in soft tissues of migratory fish has been determined using a modified diffusion model, incorporating uptake and concentration kinetics, and migratory interception as a function of sample size. Reasonably good validation was provided by information available from field studies. Differences in field data and a hypothetical release of strontium-90-oxide were examined. For 750 curies of strontium-90-oxide released, probably contamination of economically important pelagic fish would be accordingly less than consequent on a water concentration maintained at 1 million parts/cubic centimeters. Limitations to this model are discussed. Problems arising chiefly concern behavior of sedentary organisms, and biological uptake during very protracted release conditions. In these two cases present state-of-the-art does not permit adequate assessment of radiocontamination. The localized release considered here cannot constitute a potential hazard to man if normal radiation protective actions are implemented.

1240. Vermeer, K. 1972. The crayfish, Orconectes virilis, as an indicator of mercury contamination. Canad. Field-Natur. 86(2):123-125.

Crayfish (Crustacea) are good indicators of mercury contamination in different water bodies. Crayfish muscle contains three times as much mercury as the remaining body. Mercury levels do not differ significantly in samples collected from various parts of the shore of a highly contaminated lake.

1241. Vermeer, K., and F.A.J. Armstrong. 1972. Correlation between mercury in wings and breast muscles in ducks. Jour. Wild. Manag. 36(4):1270-1273.

Significant positive correlations were found between levels of mercury in wing muscles and breast muscles in each of five species of ducks. Average ratios of mercury levels in wing muscle to those in breast muscle ranged from 0.70:1.00 to 0.75:1.00 in those species.

1242. Vermeer, K., F.A.J. Armstrong, and D.R.M. Hatch. 1973. Mercury in aquatic birds at Clay Lake, Western Ontario. Jour. Wild. Manag. 37(1):58-61.

Total mercury levels ranging from 2 to 16 mg/kg in eggs did not appear to affect hatching and fledging of herring gulls (*Larus argentatus*). Mercury levels in breast muscles of 5 American widgeons (*Mareca americana*), 16 mallards (*Anas platyrhynchos*), 17 blue-winged teals (*Anas discors*), 21 common goldeneyes (*Bucephala clangula*), 17 common mergansers (*Mergus merganser*), and 7 hooded mergansers (*Lophodytes cucullatus*) averaged 0.5, 6.1, 6.5, 7.8, 6.8, and 12.3 mg/kg respectively at Clay Lake 4-6 weeks prior to the hunting season in 1971. Methylmercury in five ducks ranged from 69% to 99% of total mercury. Crayfish (*Orconectes virilis*) muscle contained the highest mercury levels of food items found in esophagi and stomachs of ducks; the high values in breast muscles of hooded mergansers are likely related to their feeding on crayfish.

1243. Vernberg, W.B., and J. O'Hara. 1972. Temperature-salinity stress and mercury uptake in the fiddler crab, *Uca pugilator*. Jour. Fish. Res. Bd. Canada 29:1491-1494.

Uptake of Hg-203 was determined in gill and hepatopancreas tissue from fiddler crabs maintained under 6 temperature-salinity regimes. Although total mercury was relatively constant under all experimental conditions, mercury levels in each of the tissues examined was markedly different. At higher temperatures the crabs seem able to transport mercury from gill tissue to the hepatopancreas more effectively than at lower temperatures. This could be a factor in the toxicity of mercury to fiddler crabs at low temperatures.

1244. Vernberg, W.B., and J. Vernberg. 1972. The synergistic effects of temperature, salinity, and mercury on survival and metabolism of the adult fiddler crab, *Uca pugilator*. U.S. Dept. Comm., Fish. Bull. 70(2):415-420.

Gill tissues of fiddler crab were the major site of mercury concentration; lesser amounts accumulated in the hepatopancreas and green gland. Very small amounts were found in the carapace and muscle tissue. No significant differences in the amount of mercury in tissues of males and females were found. A concentration of mercury sublethal to fiddler crabs under optimum conditions of temperature and salinity greatly reduced survival times when crabs were placed under conditions of temperature and salinity stress. Males were more susceptible to the synergistic effects of mercury in combination with environmental stress than females. Metabolic rates of male and female fiddler crabs were affected by prolonged exposure to mercury both under optimum environmental conditions and under temperature and salinity stress. Metabolic rates of males were more adversely affected than those of females.

1245. von Hentig, R. 1971. Influence of salinity and temperature on the development, growth, reproduction and energy budget of *Artemia salina*. Marine Biology 9:145-182.

The influence of salinity and temperature on various life processes of *Artemia salina* (L.) from Great Salt Lake, Utah, was measured at all *combinations of 4* temperature levels (10°, 15°, 20°, 30°C) and 4 salinity levels, (5, 15, 32, 70°/oo). Optimal temperature-salinity combinations differ for different life cycle stages and parameters. The hatching rate rises with increased temperature and sinks with increased salinity. Hatching success is optimal at 20°C and 32°/oo. Larval growth is best at 30°C and 15°/oo; however, maximum growth is attained at 20°C and 32°/oo. Maturation rate, onset of reproduction, interval between clutches as well as the total number of offspring are primarily influenced by temperature, whereas the clutch size is a function of salinity. As the temperature is lowered, the capacity to survive low salinities is decreased. At low temperature, reproduction is only possible at high salinity. The energy consumption of the hatching embryo is primarily determined by the salinity level of the medium and is directly proportional to it.

1246. Vosjan, J.H. 1969. Effect of chelation on the uptake and loss of yttrium-91 by *Porphyra*. Netherlands Jour. Sea Res. 4(3): 310-316.

Porphyra umbilicalis accumulates the fission product yttrium-91 in six *hours to a concentration* factor of about 288. This accumulated yttrium may be easily removed to a large extent by washing with sea water to which EDTA has been added. This proves that yttrium is only present in outer layers of the thallus, where it has accumulated by adsorption or (and) ion exchange. When stable yttrium is added, the concentration factor decreases in concentrations over 0.008 mg/l, because of Y unavailability. From sea water containing 10^{-5} M EDTA, *Porphyra* extracts little yttrium because the yttrium is chelated.

1247. Vosjan, J.H., and G.J. Van der Hoek. 1972. A continuous culture of *Desulfovibrio* on a medium containing mercury and copper *ions. Netherlands* Jour. Sea Res. 5(4):440-444.

It was determined that once a continuous culture of *Desulfovibrio* is in progress the toxic effects of Hg and Cu are nullified and do not affect the growth of the organisms. Atomic absorption analyses showed that the elements had been removed from the liquid. Similar experiments carried out on batch cultures of *Desulfovibrio* caused the cessation of all growth. It appears that microbiological processes of the sort that occur in continuous cultures, could be used to render toxic metals innocuous, to remove them from polluted waters, and to fix them as sulphides.

1248. Vucetic, T., W.B. Vernberg, and G. Anderson. 1974. Long-term annual fluctuations of mercury in the zooplankton of the east central Adriatic. Rev. Intern. Océanogr. Médicale 33:75-81.

The mercury content was determined in zooplankton (dry weight) collected from two stations in the coastal area from 1964-1969 and from one station in the deep Adriatic between 1967-1969. In the coastal area the highest values from 3 to 16 mg/kg Hg were found in 1964-1965 samples, decreasing to approximately 2.0 mg/kg for the other years. Zooplankton from the deep Adriatic from 1967-1969 averaged 2.86 mg/kg Hg.

1249. Wagner, S.L. 1973. Arsenic and cadmium in the environment. *In* Heavy Metals in the Environment. Proc. Sem. Oregon State Univ., Corvallis, Fall Quarter 1972: Oregon State Univ. Water Resources Res. Inst. Rept. SEMN WR 016.73:45-57.

Arsenic is ubiquitous in our environment and can be found in air,soil, or water. Most concentrations in water and air are in the range of a few parts per billion, whereas soil concentrations are often a few parts per million. The element does not appear to accumulate in the food chain, and most foods do not contain high concentrations of arsenic with the single exception of seafoods. For example, whereas an arsenic tolerance in foods has been established as about 3 mg/l, seafoods normally contain concentrations of arsenic ranging from 2 to 30 mg/l. Cadmium occurs naturally in only trace amounts with the exception of a relatively high concentration found in association with zinc and lead. Most exposure has been from occupational exposure in workers involved in battery manufacture, electroplating, the making of alloys, welding and solders, ceramics, and vapor lamps. Cadmium is believed to inhibit the synthesis of iron into hemoglobin, and therefore may produce a secondary type of iron deficiency anemia. As with arsenic, the compound generally exhibits toxicity via the gastrointestinal route, but, again, the inhalation of cadmium fumes is much more toxic than the ingestion of the cadmium salts.

1250. Walker, J.B. 1953. Inorganic micronutrient requirements of *Chlorella*. I. Requirements for calcium (or strontium), copper, and molybdenum. Arch. Biochem. Biophys. 46:1-11.

Procedures have been described for demonstrating requirements of the green alga, *Chlorella pyrenoidosa*, for calcium (or strontium), copper, and molybdenum, in addition to the previously established requirements for iron, manganese, and zinc. Although other micronutrient requirements are specific for the metal in question, the calcium requirement can be satisfied by strontium, on an approximately equimolar basis.

1251. Waller, W.T., and J. Cairns, Jr. 1972. The use of fish movement patterns to monitor zinc in water. Water Research 6:257-269.

The feasibility of using fish movement patterns measured by light beam interruption as a technique for continuous monitoring of the response of fish to zinc was investigated. The apparatus does not in any way interfere with fish movement within the test chamber and allows for the maintenance of fish for long time periods. Under the conditions described the system detects aberrations in fish movement caused by zinc. The detection of stress occurs in sufficient time to permit survival of the test fish if stress conditions are reversed at time of detection. The lowest concentration of zinc detected by the system during a 96-h exposure was between 3.64 and 2.94 mg/Zn^{2+}/1. The system's range of effective measurement as related to turbidity is discussed. The methodology should detect other toxicity equally well.

1252. Waller, W.T., M.L. Dahlberg, R.E. Sparks, and J. Cairns, Jr. 1971. A computer simulation of the effects of superimposed mortality due to pollutants on populations of fathead minnows (*Pimephales promelas*). Jour. Fish. Res. Bd. Canada 28:1107-1112.

This computer simulation study tested the effects of 99 levels of proportional mortality on fathead minnow (*Pimephales promelas*) populations assuming a fixed parent-progeny relationship. Limited data from two studies on three lakes were available to fit the model and obtain estimates of parameters for fathead minnow populations. Based on these estimates, 25 replications of a 50-generation cycle were simulated under two levels of environmental variability. Arbitrary extinction levels of 5, 100, and 500 females had little effect on the results. Increasing environmental variation lowered the percentage mortality at which population extinctions occurred. In general, the results are compatible with the recommendation of the U.S. Committee on Water Quality Criteria, that the maximum concentration of zinc to which fish could be continuously exposed should not exceed 0.01x the LC-50 (96 h) value—a concentration that caused a 50% reduction in mean number of eggs laid per female by fathead minnows in a laboratory study.

1253. Walter, C.M., F.C. June, and H.G. Brown. 1973. Mercury in fish, sediments, and water in Lake Oahe, South Dakota. Jour. Water Poll. Contr. Fed. 45(10):2203-2210.

Analyses for total mercury content were made of fish, sediment, and water samples collected in several locations in Lake Oahe, South Dakota, and its tailwaters. Mercury concentrations equal to or exceeding 0.5 mg/kg occurred in 30 of 225 fish samples tested (13%). Higher concentrations were found most frequently in predatory game fishes, primarily northern pike and walleye, from the Cheyenne River arm. Sediment samples with mercury concentrations above 0.5 mg/kg were found only in the Cheyenne River arm, but water samples contained only negligible amounts of mercury.

1254. Wang, H. 1959. Analyses of a toxic factor, lethal to *Paramecium* present in non-glass-distilled water. Proc. Soc. Exp. Biol. Med. 101:682-685.

The toxic effects of chloride, sulfate and nitrate of Cu and acetate of Pb and Zn on *Paramecia aurelia* were tested. The threshold concentration, i.e. the concentration causing death of all or nearly all paramecia in 20-30 min, of Pb acetate was 25^{-4} M.

1255. Ward, J.V. 1973. Molybdenum concentrations in tissues of rainbow trout (*Salmo gairdneri*) and kokanee salmon (*Oncorhynchus nerka*) from waters differing widely in molybdenum content. Jour. Fish. Res. Bd. Canada 30:841-842.

Concentrations of molybdenum in tissues of trout from three waters increased only slightly with increase in molybdenum concentration of the water. Fish from high (300 µg/l) molybdenum water had mean concentrations of 13-332 µg/l on a wet-weight basis; those from low (6 µg/l) molybdenum water, 10-146 µg/l; and those from trace molybdenum water, 5-118 µg/l. Trout exhibited generally higher molybdenum concentrations than salmon in high molybdenum water. A possible plateau mechanism concerning molybdenum accumulation by salmonids is discussed.

1256. Watson, D.G., J.J. Davis, and W.C. Hanson. 1961. Zinc-65 in marine organisms along the Oregon and Washington coasts. Science 133:1826-1828.

The concentration of zinc-65 in marine animals and plants near the mouth of the Columbia River is presented. Amounts of radiozinc found in biota diminished rapidly with distance from river mouth. Highest levels were found in plankton, algae, and mollusks. Of the human foods, oysters exhibited the highest levels.

1257. Weir, P.A., and C.H. Hine. 1970. Effects of various metals on behavior of conditioned goldfish. Arch. Environ. Health 20(1): 45-51.

A conditional avoidance technique was utilized to assess deleterious effects of salts of As, Pb, Hg and Se on fish. All test ions, arsenic, lead, mercury, and selenium impaired performance at 1/100 of the lethal concentration. Mercury was the most potent, producing measurable effects at 0.003 mg/l. Behavioral toxicity techniques are suggested as useful in setting water quality standards.

1258. Weisbart, M. 1973. The distribution and tissue retention of mercury-203 in the goldfish (Carassius auratus). Canad. Jour. Zool. 51(2):143-150.

Goldfish injected intraperitoneally with Hg-203$(NO_3)_2$ lost mercury at an apparent constant rate resulting in a biological half-life of 568h. Correlated with this loss was a linear increase in the amount of mercury in the water. The mercury-203 content in the tissues displayed four different responses: (1) gall bladder, gonad, and spleen tissues showed no significant regressions; (2) eye, kidney, and intestinal tissues manifested significant losses of mercury, but the rate of loss was not significantly different from that of the body as a whole; (3) gill, heart, skin, and swim bladder tissues lost mercury at rates faster than the body as a whole; and (4) brain, liver, muscle, and head kidney tissues showed no significant losses of mercury.

1259. Weiss, H.V., and W.H. Shipman. 1957. Biological concentration by killer clams of cobalt-60 from radioactive fallout. Science 125:695.

After the March 1954 nuclear detonation in the Pacific Ocean, a number of northern Marshall Islands were contaminated with radioactive fallout. Among the specimens collected at two years postdetonation were two "killer" clams (Tridacna gigas) that were recovered from the shores of Rongelap Island. High levels of Co-60 were detected in soft tissues.

The appearance of readily measurable quantities of Co-60 in the killer clam is noteworthy from two aspects. First, Co-60 is not a component of fission products. It is therefore assumed that this nuclide was induced from an environmental precursor by the neutron flux accompanying the nuclear detonation. A possible precursor is natural Co-59, which, when bombarded by neutrons, undergoes the typical (n, γ) reaction to form Co-60. More importantly, this radioelement was not detected in the numerous fallout-exposed materials analyzed at one year postdetonation. The accumulation of Co-60 from an environment which for all intents and purposes was infinitely dilute points to the enormous concentrating capacity of the killer clam.

1260. Westöö, G. 1966. Determination of methylmercury compounds in foodstuffs. I. Methylmercury compounds in fish, identification and determination. Acta Chemica Scandinavica 20:2131-2137.

A combined gas chromatographic and thin-layer chromatographic method for the identification and determination of methylmercury compounds in fish is presented. For the identification five derivatives of the supposed methylmercury compound from three samples of fish were studied. In thirty samples of fish from the Baltic, Swedish lakes and rivers two or three derivatives were analyzed using both chromatographic methods. The samples contained 0.07-4.45 mg Hg/kg as methylmercury compounds. Also in marine fish methylmercury compounds were found, but only in small amounts. Any methylmercury attached to a sulphur atom of nonvolatile compounds will not be determined with this method.

1261. Westöö, G. 1973. Methylmercury as precentage of total mercury in flesh and viscera of salmon and sea trout of various ages. Science 181:567-568.

The proportion of methylmercury to total mercury in the flesh of salmon 1 to 7 years old and sea trout (Salmo ocla) 1 and 2 years old was found to average 93% with a range of 81 to 98%, and to be independent of age of fish. In salmon and sea trout 1 and 2 years old, methylmercury constituted 26 to 67% of the total visceral mercury, without age dependence.

1262. Weswig, P.H. 1973. Selenium in the environment. In Heavy Metals in the Environment; Proc. Sem. Oregon State Univ., Corvallis, Ore., Sept. 1972: Oregon State Water Resources Res. Inst. Rept. SEMN WR 016.73:183-203.

Selenium is a relatively scarce element, its mean content in the earth's crust is about 0.09 mg/kg, and it is 66th in order of abundance. Selenium occurs especially in association with sulfur deposits and may also be found in combination with elements such as iron, lead, copper, and arsenic. In most soils not derived from sedimentary rocks, Se concentration is about 0.05 mg/kg. In sea-bottom sediments and sedimentary rocks, selenium values may be as high as 1.2 mg/kg. However, there are certain seleniferous regions in the world with much greater concentrations of selenium. In addition to South Dakota and Wyoming, seleniferous areas have been reported in Canada, Mexico, Ireland, Australia, Israel, and China. The safe upper limit for selenium in drinking water is 10 μg/l according to the U.S. Department of Health. The presence of selenium in surface waters is a function of both pH and drainage slope with the highest concentrations coming generally from specific spring waters. Plants which grow on soils rich in selenium may concentrate the selenium and cause death to the animal consuming them. In Wyoming and North Dakota, there are more than 24 species which may be classified as accumulators. Chronic selenium poisoning is caused by consuming plants containing from 10-30 mg/kg selenium.

1263. Whitton, B.A. 1970. Toxicity of zinc, copper and lead to *Chlorophyta* from flowing waters. Archiv fur Mikrobiologie *72:353-360.*

The biological and economic interest of heavy metals in the relation to freshwater algae led to a survey of toxicity of zinc, copper, and lead to *Chlorophyta* in flowing waters. Twenty populations each of *Stigeoclonium tenue* and *Cladophora glomerata* were tested for variations in metal resistance. The only indication found was a slight increase in resistance to zinc of one *Stigeoclonium* population from a metal-polluted stream. Thirty-five other algal populations, representing about 25 species, were also tested. Comparison of these populations showed that *Cladophora glomerata* was almost always the most sensitive to all three metals; this species was absent from streams known to be polluted by lead or lead and zinc. The Ulotrichales and most of the Zygnemales were relatively resistant to zinc, while all the *Oedogonium* species taken from the field were sensitive to zinc. However, an *Oedogonium* population highly zinc resistant was obtained from a zinc enriched laboratory tank. Because the medium used in the present experiments is relatively rich in nutrients, such as phosphates, it may well mask effects that would show in a less favorable environment.

1264. Whitton, B.A. 1970. Toxicity of heavy metals to freshwater algae: A review. Phykos 9:116-125.

A brief review of the literature on toxicity of heavy metals (Pb, Zn, Fe, Cu, Cr, Ag, Mn and Hg) to freshwater algae is presented. Subtopics include: exposure over long periods; laboratory studies; and possibility of adaptation. A bibliography of 38 references is appended.

1265. Wiesepape, L.M., D.V. Aldrich, and K. Strawn. 1972. Effects of temperature and salinity on thermal death in postlarval brown shrimp, *Penaeus aztecus*. Physiol. Zool. 45(1):22-33.

Interest has been expressed in the possibilities of commercial mariculture of brown shrimp which naturally occur in bays in the Northwest Gulf of Mexico. The lethal temperature for shrimp acclimated at the same salinity and different temperatures was determined. Thermal resistance of postlarvae transferred to a higher temperature with two salinities was measured at timed intervals to determine differences in acclimation. To determine effects of changes in temperature and salinity at the same time, a large number of postlarval shrimp acclimated at various temperature-salinity combinations were subjected to various other temperature-salinity conditions. The level of thermal resistance does not seem to be affected by reduced salinity. It now seems possible to raise brown shrimp from the egg to the postlarval stage under hatchery conditions. The effects of heated effluents on postlarval brown shrimp depend primarily on the temperature of the effluent and the temperature at which the shrimp are acclimated. Secondary considerations are salinity and acclimation salinity.

1266. Williams, L.G., and D.I. Mount. 1965. Influence of zinc on periphytic communities. Amer. Jour. Bot. 52(1):26-34.

The glass-slide technique was used in a 14-week study to show effects of 4 concentrations of zinc on periphytic communities in 4 outdoor canals supplied with running pond water containing its natural biota. No species was found that could be considered an indicator of zinc. The effect of adding 1 mg/l or more of zinc was to reduce the number of dominant species. A geometric regression of the average number of dominant algal species was found beginning with the control, with no added zinc, and proceeding from that to the largest concentration of zinc. A relatively large concentration of zinc resulted in comparatively low biotic diversity. Fungi and slime-forming bacteria produced a large standing crop in the largest zinc concentration, apparently by digesting the killed incoming phytoplankters that were used as their food.

1267. Williams, P.M., and H.V. Weiss. 1973. Mercury in the marine environment: Concentration in sea water and in a pelagic food chain. Jour. Fish. Res. Bd. Canada 30(2):293-295.

Mercury in seawater, in a pelagic food chain, and in bottom sediment was determined at a single station 430 km southeast of San Diego, California. The concentration of mercury in zooplankton slightly increased with depth of collection. The mercury content in almost all of the higher trophic levels of organisms collected at greater depths was indistinguishable from the concentration of mercury in zooplankton at these depths. Mercury concentration in the seawater column was essentially constant below 100 m and significantly higher at the surface. This vertical profile of mercury content is not ascribable to biological activity.

1268. Wilson, R.C.H. 1972. Prediction of copper toxicity in receiving waters. Jour. Fish. Res. Bd. Canada 29(10):1500-1502.

The 96-hr LC-50 of copper to Atlantic salmon parr in water taken from the Exploits River, Newfoundland, is about 125 μg/l at a total hardness of 8-10 mg/l $CaCO_3$ and a total alkalinity of 4 mg/l. However, the addition of spent sulphite liquor from a pulp mill allowed fish to survive more than 180 μg/l Cu. Considering the variety of organic compounds which have now been shown to chelate dissolved copper, it is likely that a simple model for the prediction of copper toxicity in waters receiving mine effluent will prove impossible.

1269. Windom, H., R. Stickney, R. Smith, D. White, and F. Taylor. 1973. Arsenic, cadmium, copper, mercury, and zinc in some species of North Atlantic finfish. Jour. Fish. Res. Bd. Canada 30(2): 275-279.

Arsenic, cadmium, copper, mercury, and zinc analyses of 91 individuals representing 35 species of North Atlantic finfish (Chondrichthys and Osteichthys) indicate that these metals occur at similar levels in both inshore and offshore species. Chondrichthys and Osteichthys have similar concentrations of all the metals, excepting arsenic which is higher in Chondrichthys. Analyses of various tissues in Chondrichthys reveal higher metal concentrations in the liver except for mercury which was higher in muscles.

1270. Windom, H., F. Taylor, and R. Stickney. 1973. Mercury in North Atlantic plankton. Jour. Cons. Int. Explor. Mer. 35(1):18-21.

Concentrations of mercury in North Atlantic plankton (on a dry weight basis) vary from less than 0·2 to about 0·4 mg/kg in unpolluted areas to as high as 5·3 mg/kg in polluted areas near shore. No correlation in mercury content with species composition of the plankton samples was observed. Variations in concentration appear to be a function of distance from coastal pollution sources.

1271. Windom, H.L. 1973. Mercury distribution in estuarine-nearshore environment. Jour. Amer. Soc. Civil Engin.; Waterways, Harbors and Coastal Engin. Div. 99(WW2):257-264.

The transfer of Hg through an estuarine system of the southeastern Atlantic coast to the open ocean is controlled by mixing of estuarine waters with offshore waters, loss in plant detritus due to rafting offshore, and migration of estuarine organisms to offshore areas. An additional loss of Hg from the estuarine system is due to sedimentation. A Hg budget for estuaries along the Georgia coast indicated that the dominant salt marsh plant, *Spartina alterniflora*, exerts a strong control on the migration of the metal. Mercury enters the estuary primarily in solution, delivering approximately 1.5 mg annually to each square meter of salt marsh. The annual uptake of Hg by the plant is approximately 0.7 mg/m^2 of salt marsh.

1272. Windom, H.L., and R.G. Smith. 1972. Distribution of iron, magnesium, copper, zinc, and silver in oysters along the Georgia coast. Jour. Fish. Res. Bd. Canada 29:450-452.

The shells and soft tissues of approximately 50 oysters (*Crassostrea virginica*) collected along the Georgia coast were analyzed for Fe, Mg, Cu, Zn, and Ag. Magnesium was the only metal found to be more concentrated in the shells. Correlations between metals in the soft tissues suggest that iron and magnesium, and copper, zinc and silver form two separate groups of metals which are concentrated similarly by the oyster. Geochemical characteristics of a given metal are an important control in their input by oysters.

1273. Winner, J.E. 1972. Macrobenthic communities in the Coeur d'Alene lake system. M.S. Thesis. Available from Nat. Tech. Inf. Ser., Springfield, Va., as OWRR B-015-IDA(2):1-41.

The extent of contamination by mine and smelter wastes in the Coeur d'Alene lakes, Idaho was studied by measuring concentrations of five heavy metals in the sediments and studying their possible effects on benthic communities. Zinc concentrations were 627-7320 mg/l in Lake Coeur d'Alene and 10-105 mg/l in Chatcolet and Round Lakes. Benthic macroinvertebrates were collected and identified from four depths in four areas of Lake Coeur d'Alene in July and September 1971 and in March 1972 to determine distribution and relative numbers. Chironomid larvae and oligochaetes made up 90% of the 62 taxa of macroinvertebrates identified. The most commonly collected organisms were chironomids in Lake Coeur d'Alene and oligochaetes in Round and Chatcolet Lakes. Macroinvertebrates were most abundant in shallow water where aquatic macrophytes were common. Sixty percent of the organisms were found in samples from 2 m, but wide variation was observed. Distribution of benthic chironomids or oligochaetes did not seem to be substantially affected by 1000-7000 mg/l zinc and other metals in the sediments. Southern portions of the lake system contained many macroinvertebrates associated with nutrient-rich waters while the northern portions contained many organisms associated with oligotrophic waters.

1274. Winter, J.E. 1972. Long-term laboratory experiments on the influence of ferric hydroxide flakes on the filter-feeding behavior, growth, iron content and mortality in Mytilus edulis L. In Ruivo, M. (ed.). Marine Pollution and Sea Life. Fishing Trading News (books) Ltd., London: 392-396.

During a 5 month study adult mussels were subjected to various concentrations (0.4-4.0 mg Fe/l) of ferric hydroxide flakes together with their algal food. At low iron applications of 0.4 mg Fe/l and in controls, no production of pseudofaeces took place. All flakes and food were transported into the stomach. At higher applications, pseudofaeces production was abundant. At the highest application of 4.0 mg Fe/l, almost all ferric hydroxide flakes and algal cells were disposed of as pseudofaeces. Growth of soft tissues decreased with increasing applications of ferric hydroxide flakes; iron content increased with increasing concentrations. At the highest application (4.0 mg Fe/l), iron content/unit dry wt of soft parts increased 9x within 3 months, but since there was a 38% weight loss associated with this treatment, the increase of iron content per animal was only 3x over initial values. High and medium amounts of ferric hydroxide flakes caused a mortality of 75% within 3 months. Low applications killed 40% within 5 months; controls experienced 20% mortality during this period. The low rate of mortality during the first month at high application of 4.0 mg/l is noteworthy. Apparently, very high applications can be tolerated for a short time because almost the total amount is refused and returned as pseudofaeces while only a small amount of iron enters the digestive tract.

1275. Wixson, B.G. and E. Bolter. 1972. Evaluations of stream pollution and trace substances in the New Lead Belt of Missouri. Trace Substance in Environmental Health 5:143-152.

Studies of lead-zinc mine effluents entering streams have indicated that mining waste-waters contain carbon dioxide and sufficient phosphorus to combine with nitrogen present in the stream water and cause undesirable benthic growths in bacterial-algal mats. Background concentrations of lead, zinc and copper rarely exceeded 20 µg/l in streams; however, concentrations up to 1,000 µg/l have been determined in settling ponds. Recommendations are presented for the effective control of trace substances associated with wastewater from the lead-zinc industry in southeast Missouri.

1276. Wolfe, D.A. 1970. Levels of stable Zn and ^{65}Zn in *Crassostrea virginica* from North Carolina. Jour. Fish. Res. Bd. Canada 27(1):47-57.

The concentration of zinc in oysters was highly variable—samples from relatively unpolluted estuaries of North Carolina contained, on the average, 85-245 mg/kg zinc, based on wet weight. Internal tissues, like adductor muscle and pericardial sac, had zinc levels less than half those of external tissues but zinc was nonetheless distributed uniformly throughout animal tissues. During 1964-66, North Carolina oysters contained 2-20 pCi Zn-65 from fallout per 100 g wet weight. Specific activity of Zn-65 in these oysters during 1965-66 was in the range 90-300 pCi/g Zn, and was declining with an apparent half-life of 276 days.

1277. Wolfe, D.A. 1971. Fallout cesium-137 in clams (*Rangia cuneata*) from the Neuse River Estuary, North Carolina. Limnology and Oceanography 16:797-805.

The concentration of Cs-137 from fallout was determined for the soft tissues of clams from the Trent-Neuse estuary during 1965-1967. The concentration of Cs-137 in clams varied inversely as a logarithmic function of salinity in the estuary, but with a lesser salinity dependence than reported previously for Cs-137 concentration factors in *Rangia*. An increasing concentration gradient of Cs-137 with increasing salinity in the estuary was hypothesized and confirmed by analysis of Cs-137 in estuarine water of varying salinity. Transport of Cs-137 on sediments into estuaries, coupled with ion-exchange displacement of Cs-137 from sediments at elevated salinities, is proposed to account for concentration gradients of Cs-137 in the estuary.

1278. Wolfe, D.A., and C.B. Coburn, Jr. 1970. Influence of salinity and temperature on the accumulation of cesium-137 by an estuarine clam under laboratory conditions. Health Physics 18:499-505.

Accumulation of Cs-137 by the clam *Rangia cuneata* was described by asymptotic expotential regressions at 20 salinity-temperature combinations (1-20°/oo, 5-25°C). Regression constants from the individual experiments were subjected to regression analysis and were expressed as functions of salinity and temperature. Concentration factors decreased with increasing salinity, but increased with temperature. The proportion of Cs-137 associated with the shell decreased as salinity or temperature was increased.

1279. Wolfe, D.A., F.A. Cross, and C.D. Jennings. 1973. The flux of Mn, Fe and Zn in an estuarine ecosystem. In Radioactive Contamination of the Marine Environment, Int. Atom. Ener. Agen., Vienna, Austria: 159-175.

Trace metal (Mn, Fe, Zn) fluxes are modelled for the Newport River estuary, a North Carolina embayment of about 31 square km which receives runoff from a 340 square km watershed. The estimate is relevant for prediction of radionuclide distributions (with respect to uptake by commercial fish and shellfish) for the case of chronic input. (Further information as to critical pathways and turnover rates would be required for discontinuous inputs.) The greatest export is sedimentation. Major inputs are dissolved and suspended material in river water, and possibly the sea when the river flow is low. A lesser input is uptake from interstitial water and deep sediments by the dominant vegetation, *Spartina alterniflora*.

1280. Wong, K.M. 1971. Radiochemical determination of plutonium in sea water, sediments and marine organisms. Anal. Chim. Acta 56:355-364.

A radiochemical procedure is described for the determination of plutonium in large samples of sea water, sediments, liver and bone of shark, and whole blue mussel. Factors influencing the recovery, contamination and blank activity are discussed. Pu-239 activity in liver, bone, and whole mussel were, in d/m/kg wet wt, about 0.25, 0.03, and 0.33, respectively.

1281. Wong, K.M., V.F. Hodge, and T.R. Folsom. 1972. Plutonium and polonium inside giant brown algae. Nature 237(5356):460-462.

The giant brown alga, *Pelagophycus porra*, was sampled to determine plutonium and polonium levels in sea water. The samples were analyzed by alpha spectrometry for Pu-239 and Po-210 content. Polonium concentrations in outermost thin layers of the algae were 1,000 times greater than those from inner layers; highest concentrations of plutonium were also found in outer layers. These differences in sensitivity within a single species suggest that, when comparing two different environments, identical sample tissue from a certain species should be compared. Sampling thin parts of brown algae, or thin outer layers should provide great sensitivity for detecting early changes in extremely small traces of plutonium which are expected to accumulate in oceans due to reactor effluents, nuclear fuel processing and fallout.

1282. Wood, J.M. 1973. Metabolic cycles for toxic elements in aqueous systems. In 6th Int. Symp. Medicale Ocean., Portoroz, Yugoslavia, Sept. 26-30, 1973:7-16.

When elements are introduced into environments rich in microbial activity, each valence state is made available for metabolic interconversions. The author summarizes the mercury and arsenic cycles showing interconversion of inorganic complexes to organometallic complexes. These are considered important because the latter are readily transported and accumulated into tissues of high lipid content. This interconversion is accomplished with methylating agents which are available for methyl transfer reactions in biological systems.

1283. Wooldridge, C.R., and D.P. Wooldridge. 1969. Internal damage in an aquatic beetle exposed to sublethal concentrations of inorganic ions. Annals Entomolog. Soc. America 62(4):921-922.

The effects are reported of metal ions (Co, Mn, Cr, Mg, Zn, Cd, Cu, Ni, Ca, Al, Mo, Fe) in sublethal concentrations upon the gross internal anatomy of adult aquatic beetles (Tropistermus lateralis nimbatus). All test solutions were .003 M. The fat body was the first and most severely affected tissue, its color changing from lemon yellow to white through shades of very dark orange. Other, less universal, changes are also described. Variations in gonadal condition would be the most useful criterion for determining inorganic contamination of the aquatic habitat of this organism.

1284. Wooldridge, D.P., and C.R. Wooldridge. 1967. Some effects of inorganic pollution on an aquatic beetle. Proc. North Central Branch Entomol. Soc. Amer. 22:160-161.

Concentrations of 10^{-2} M of Cd, Co, Mn, Cr, Ni and Cu salts killed Tropistermus lateralis nimbatus in less than 10 days. There were no measurable effects on survival and behavior in 14 days at 10^{-2} M concentrations of salts of Al, Fe, Mg, Mo and Zn.

1285. Wright, T.D., D.G. Leddy, D.J. Brandt, and T.T. Virnig. 1973. Water quality alteration of Torch Lake, Michigan by copper leach liquor. Proc. 16th Conf. Great Lakes Res.: 329-344.

In the summer of 1972, Torch Lake was found to have very high levels of copper, carbonate alkalinity, pH and ammonia nitrogen in comparison to previous years. In addition, unusual oxygen depletion in the hypolimnion was noted. Bioassays with adult amphipods indicated that portions of the lake were toxic. Behavior of the chlorides in the lake showed that observed conditions were not caused by accumulation in the basin, but probably resulted from spills of cupric ammonium carbonate known to have occurred in late fall 1971 and early summer 1972. Volumetric calculations indicate that the spill could have resulted in copper values much greater than those observed and could have (through conversion of ammonia nitrogen to nitrate nitrogen) been significantly involved in oxygen depletion. There is also evidence of change in the phytoplankton community, but the causal mechanism is not clear. Theoretical calculations indicate that Torch Lake, which has one of the highest copper concentrations in the United States, should not support aquatic life. That it does illustrates a hiatus in the role of various ionic species of copper and aquatic life.

1286. Young, D.R., and T.R. Folsom. 1973. Mussels and barnacles as indicators of the variation of ^{54}Mn, ^{60}Co and ^{65}Zn in the marine environment. *In* Radioactive Contamination of the Marine Environment. Int. Atom. Ener. Agen., Vienna, Austria: 633-650.

The intertidal byssal mussel *Mytilus californianus* and the oceanic gooseneck barnacle *Lepas anatifera* are efficient indicators of the marine environment. *Lepas* specimens collected from the northeastern Pacific during the first half of 1964 demonstrated oceanic-to-coastal ratios of Mn-54, Co-60, and Zn-65 fallout from the 1961-62 thermonuclear tests of approximately 3:1, 4:1, and 2:1, respectively. Cesium-137 in the surface layers of the two sectors (whose centers lie about 1500 and 300 km west of San Diego) also showed a 3:1 oceanic-to-coastal enhancement of fallout from this source. *Mytilus* specimens collected during 1963-64 along the northeastern Pacific Coast showed a fairly uniform distribution of Mn-54 and Co-60 between latitudes 46 and 29° north, but dramatically reflected the point source of Hanford-produced Zn-65 emanating from the mouth of the Columbia River. Relatively high Zn-65 concentration, possibly related to this source, were detected in *Mytilus* from northern Baja California, Mexico—1900 km to the south. Except for a late 1963 peak in Mn-54 concentrations in southern California *Mytilus*, the ecological half-times of the three nuclides observed in the invertebrates between mid-1963 and late 1964 at specific intertidal, coastal, and oceanic platforms were consistent with radioactive decay rates. This suggests an approximate equilibrium between input and removal of these radiometals in mixed layer. Mussel and barnacle tissue-to-seawater enrichment factors for the three nuclides exceed 1000. In *Mytilus* 4 to 6 cm in length, size variations had no significant effect on nuclide concentration, but 70% of the Co-60 and Zn-65 soft-tissue radioactivity was located in kidneys and digestive glands of this organism. Bay mussels (*M. edulis*) taken from the coastal surf zone showed concentrations similar to those in *M. californianus*, but *M. edulis* in two nearby bays had lower values. Intertidal coastal mussels and gooseneck barnacles recently collected from 14 California stations indicate average 1971 "baseline concentrations" of Mn-54, Co-60, and Zn-65 of 0-5, 0-4, and 0-11 pCi/wet kg, respectively.

1287. Young, L.G., and L. Nelson. 1974. The effects of heavy metal ions on the motility of sea urchin spermatozoa. Biol. Bull. 147:236-246.

Optimum motility of sea urchin spermatozoa for a period adequate to initiate the process of fertilization requires an apparently critical level of certain heavy metal ions. Increase of some of the divalent cations above the "normal" seawater content accelerates or depresses the swimming speed in dose- or time-dependent fashion (or both). The different patterns of *Arbacia* sperm swimming speed response to the individual cation supplements (Cu, Zn, Mn, Hg) may reflect differences in rate of penetration into the cell, binding of active groups or selective inhibition of as yet unspecified enzymes at or below the cell surface which directly or indirectly contribute to regulation of flagellar contractility. The concentrations tested ranged from 500 nM up to 10 mM. The "optimum" concentrations fell between 1 to 10 micromolar Cu, Zn and Hg on initial exposure, while Mn was moderately inhibitory at these levels. EDTA, up to 10^{-1}molar, exerts no adverse effect on sperm propulsion, while 8 X 10^{-4} M almost completely blocks the motility. Within this short concentration span, the EDTA appears not only to bind essential seawater cations, but may also deplete those intracellular regulatory cations which otherwise may exist in a state of dynamic equilibrium with the seawater.

1288. Young, R.G., and D.J. Lisk. 1972. Effect of copper and silver ions on algae. Jour. Water Poll. Contr. Fed. 44(8):1643-1647.

A concentration of 0.3 mg/l copper or copper-silver mixture was lethal to all blue-green algae tested: *Anacystis nidulons*, *Anabaena variabilis*, *Anabaena flos-aqua*. Green algae (*Eudorina californica*, *Pediastrum biradiatum*, *Chlorella vulgaris*) were more resistant than the blue-green algae. The copper-silver combination was usually slightly more effective than copper alone under the conditions used, but will be of questionable utility in the field when the increased risk to desirable fish and the economic factor of the greater cost of silver salts are considered.

1289. Zeitoun, M.A., E.F. Mandelli, W.F. McIlhenny, and R.O. Reid. 1969. Disposal of the effluents from desalination plants: The effects of copper content, heat and salinity. Office of Saline Water, Res. Devel., Prog. Rept. 437(OWS-14-01-0001-1161):1-192.

Criteria for outfall designs were established based on copper concentrations in effluents from a desalting plant, its concentration after dispersion in the environment and the ecological effects of heat, salinity and copper on the planktonic organisms in the water column. The copper introduced into the brine from existing distillation plants averaged from 0.34 to 0.65 mg/1. Copper was found to be more soluble in seawater concentrates than in seawater, with a minimum solubility at pH 7.5. The removal of copper from brine blowdown by plating on aluminum was found to be technically unfeasible due to side reactions involving evolution of hydrogen. The use of diffusers to mix the effluent with seawater to reach safe copper concentration by dilution is believed to be a more practical solution than chemical removal or inactivation.

Copper concentrations of the order of 0.05 mg/1 at 20°C on continuous supply were found to be toxic to the two most important primary producers in the marine environment: diatoms and dinoflagellates. Increasing temperatures were found to have a synergistic action on the toxicity of Cu^{++} to marine phytoplankton. Increasing salinities were found to have an antagonistic action on the toxicity of Cu^{++} to marine phytoplankton, however, the concomitant thermal stress will minimize this effect. Copper was found to be concentrated by marine phytoplankton in the ratio of 5000:1 to 10,000:1. Considerable amount of copper can therefore be transferred to other trophic levels of the various food chains.

1290. Zimmermann, U., and E. Steudle. 1971. Effects of potassium concentration and osmotic pressure of sea water on the cell-turgor pressure of Chaetomorpha linum. Marine Biology 11: 132-137.

The unicellular littoral alga Chaetomorpha linum is capable of maintaining constant cell-turgor through regulation of internal osmotic pressure, when subjected to various salinity gradients. The decrease or increase of external potassium concentration is an important factor. This has been shown by experiments in artificial seawater with reduced osmolality and variable potassium concentration (1 to 50 mMol/1).

1291. Zitko, P., W.V. Carson, and W.G. Carson. 1973. Prediction of incipient lethal levels of copper to juvenile Atlantic salmon in the presence of humic acid by cupric electrode. Bull. Environ. Contamin. Toxicol. 10(5):265-271.

The toxicity of copper to juvenile Atlantic salmon in the presence of humic acid and predictions of incumbent lethal levels of copper from potential of a cupric ion selective electrode, are presented. The ILL of Cu is 12 μg/l; this increases with increasing concentrations of humic acid.

1292. Zitko, V., B.J. Finlayson, D.J. Wildish, J.M. Anderson, and A.C. Kohler. 1971. Methylmercury in freshwater and marine fishes in New Brunswick, in the Bay of Fundy, and on the Nova Scotia Banks. Jour. Fish. Res. Bd. Canada 28(9):1285-1291.

American eel (Anguilla rostrata), chain pickerel (Esox niger), white perch (Morone americana), yellow perch (Perca flavescens), brook trout (Salvelinus fontinalis) and Atlantic salmon (Salmo salar) contained 0.07-2.08, 0.27-1.58, 0.75-1.07, 0.20-1.05, 0.08-0.13, and 0.09 mg/kg of methylmercury, expressed as mercury on wet weight basis, respectively. With only two exceptions, levels of methylmercury in marine fish were below 0.13 mg/kg. Some of the freshwater sampling locations could be directly associated with an industrial activity in the area. The concentration of methylmercury in eels from a lake in New Brunswick did not change over a period of 46 years, indicating that elevated levels of mercury may in some instances reflect the natural situation.

SECTION III

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Three indices are presented: INDEX-METALS, INDEX-TAXA, and INDEX-AUTHORS. Each index encompasses this volume and the initial volume in this series, namely, Eisler, R. 1973. Annotated bibliography on biological effects of metals in aquatic environments (no. 1-567). U.S. Environmental Protection Agency, Report R3-73-007: pp. 1-287.

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